IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

POLAROID CORPORATION	)	
	)	
Plaintiff,	)	
	)	
v.	)	C.A. No. 06-738 (SLR)
	)	
HEWLETT-PACKARD COMPANY,	)	
	)	
Defendant.	)	

POLAROID'S *DAUBERT* MOTION TO EXCLUDE
DR. RANGARAJ RANGAYYAN'S OPINIONS CONCERNING OBVIOUSNESS

Plaintiff Polaroid Corporation ("Polaroid") hereby moves to exclude Defendant Hewlett-Packard Company's ("HP's") expert, Dr. Rangaraj Rangayyan, from offering testimony or opinions on the subject of obviousness, for the reasons set forth below.

I. INTRODUCTION

HP's expert, Dr. Rangaraj Rangayyan, renders opinions on obviousness. In order to conclude, as he did, that the asserted claims of U.S. Patent No. 4,829,381 ("the '381 patent") are invalid on obviousness grounds, Dr. Rangayyan needed to demonstrate not only that each of the elements of the claims were independently in the prior art, but also to opine, or rely on evidence in the record, that a person of ordinary skill in the art would have had a ***reason*** to combine the references and a ***reasonable expectation of success in doing so***. *Takeda Pharm. Co. Ltd. v. Teva Pharm. USA Inc.*, Civ. No. 06-033-SLR, 2008 WL 839720, at *1, *12–13 (D. Del. March 31, 2008). Although he opined that each of the elements of the '381 patent could be found in various combinations of prior art, Dr. Rangayyan did not articulate, point to, or provide any reason to combine the references, and he did not discuss or explain whether there would have been a reasonable expectation of success in combining such references. Because he did not set

forth the proper analysis, Dr. Rangayyan should be precluded from opining on obviousness.[1] *Trueposition, Inc. v. Andrew Corp.*, Civ. No. 05-747-SLR, 2007 WL 2429415, at *1, *1 (D. Del. Aug. 23, 2007) (precluding expert from testifying where he failed to set forth the proper invalidity analysis).

II. ARGUMENT

(a) Dr. Rangayyan Did Not Properly Apply The Correct Legal Standard for Obviousness.

As explained in 35 U.S.C. § 103(a), "[a] patent may not be obtained . . . if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art." 35 U.S.C. § 103(a). Obviousness is a question of law that depends on the following underlying factual inquiries called the *Graham* factors: 1) the scope and content of the prior art; 2) the differences between the art and the claims at issue; 3) the level of ordinary skill in the art; and 4) objective evidence of non-obviousness. *See KSR Int'l Co. v. Teleflex Inc.*, ___ U.S. ___, ___, 127 S. Ct. 1727, 1734 (2007) (quoting *Graham v. John Deere Co.*, 383 U.S. 1, 17–18 (1966)). An alleged infringer seeking to invalidate a patent based on obviousness grounds must do so by clear and convincing evidence. *Kao Corp. v. Unilever U.S., Inc.*, 441 F.3d 963, 968 (Fed. Cir. 2006).

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[1] Dr. Rangayyan also submitted a supplemental report on April 18, 2008. Because Dr. Rangayyan's supplemental report was submitted after the scheduled date for the submission of expert reports, Polaroid is filing herewith a motion to strike his supplemental report in addition to a myriad of other documents that HP produced late in complete disregard of the Scheduling Order. Nonetheless, even if this Court decides that Dr. Rangayyan's supplemental expert report should not be stricken, his supplemental report does not correct the significant errors of his obviousness analysis.

"[A] patent composed of several elements is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art . . . ." *KSR*, 127 S. Ct. at 1741. Rather, in order to combine prior art references to show obviousness, "it can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the [prior art] elements" in a manner claimed. *Id*. In *Takeda Pharmaceutical*, which applied the holdings of *KSR*, this Court concluded that Teva had not carried its burden of proof that the patents at issue were invalid based on obviousness grounds. *Takeda Pharm.*, 2008 WL 839720, at *12–13. Specifically, although Teva asserted that each of the components of the claimed pharmaceutical composition was disclosed in the prior art, this Court stated, pursuant to *KSR*, that Teva must also "identify some 'reason that would have prompted a person of ordinary skill in the relevant field to combine the[se] elements.'" *Id.* at *12 (quoting *KSR*, 127 S. Ct. at 1741); *see also Innogenetics, N.V. v. Abbott Labs.*, 512 F.3d 1363, 1373 (Fed. Cir. 2008) ("[K]nowledge of a problem and motivation to solve it are entirely different from motivation to combine particular references to reach the particular claimed method."). This Court further elaborated that "[i]n addition to showing that a person of ordinary skill in the art would have had reason to attempt to make the composition, Teva must demonstrate that such a person 'would have had a reasonable expectation of success in doing so.'" *Id.*[2] (quoting *PharmaStem Therapeutics, Inc. v. ViaCell, Inc.*, 491 F.3d 1342, 1360 (Fed. Cir. 2007)).

2 This Court made a similar ruling with respect to Teva's argument that the '431 patent was obvious. *Takeda Pharm.*, 2008 WL 839720, at *13. There, this Court found that Teva had "not identified a sufficient suggestion in the art for moving the 2,2,2-trifluoroethoxy group to the pyridine ring." *Id.* And, that even if it were assumed that a person of ordinary skill in the art would have been motivated to "move substituents from the benzimidazole ring to the 4-position, . . . , Teva ha[d] not proffered clear and convincing evidence that such a person would have been motivated to relocate the 2,2,2,-trifluoroethoxy substituent to this specific location with a reasonable expectation of success." *Id.*

Dr. Rangayyan did not conduct or describe in his report a proper obviousness analysis. Dr. Rangayyan merely stated that he was told that "a claim is 'obvious' if one of ordinary skill in the art would be motivated to modify an item of prior art, to combine two or more items of prior art to arrive at the claimed invention." (Exhibit A, Rangayyan Report at ¶ 133). Thereafter, Dr. Rangayyan included page after page of paragraphs stating what the alleged prior art discloses or teaches, each section concluding with a paragraph opining that the asserted claim of the '381 patent is obvious when prior art references are combined. Notably, however, not once did Dr. Rangayyan provide a reason to combine these prior art references. Nor did he discuss whether, much less establish that, a person of ordinary skill in the art would have had a reasonable likelihood of success of doing so. Instead, Dr. Rangayyan merely repeated the same two sentences with respect to each combination of alleged prior art:

> It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by [the alleged prior art] is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the [alleged prior art reference] and the Gonzalez algorithm.

(*Id.* at ¶¶ 238–243.) Dr. Rangayyan also repeatedly opined, without any support, that the claims of the '381 patent were obvious using three conclusory statements (or slight variations thereof):

> Therefore, I believe that claim [] is obvious in view of [prior art].

(*Id.* at ¶¶ 192, 194, 200–203, 246, 250, 254, 256–258.)

> Therefore, I believe claim [], as it is proposed to be construed by HP, is an obvious extension of [prior art].

(*Id.* at ¶¶ 193, 249, 282.)

> Therefore, I am of the opinion that claim [] is obvious, as that term has been explained to me, in view of [combined prior art references].

(*Id.* at ¶¶ 238–243, 251.) These repetitive statements are void of analysis or factual basis and are insufficient on their face to provide clear and convincing evidence of obviousness.

As this Court has recognized, *KSR* and its progeny require more. *See, e.g., Bayer AG v. Dr. Reddy's Labs., Ltd.*, 518 F. Supp. 2d 617, 627–28, 628 n.23 (D. Del. 2007) ("The court finds inadequate evidence to support Reddy's claim that a person of skill in the art would have been motivated to perform 7-position substituent modifications on AT-3295 or Sankyo 1-130 as compared to other prior art quinolones," and "Likewise, there is no indication that a person of skill in the art would have been motivated to perform 7-position substituent modifications on AT-3295 or Sankyo 1-130 with any reasonable expectation of success."). As discussed above, Dr. Rangayyan did not provide or rely upon the requisite expert opinion or factual evidence as to why one of ordinary skill in the art would have been motivated to combine the prior art that he combined. *See, e.g., Novartis Pharms. Corp. v. Teva Pharms. USA Inc.*, Civil Action No. 05-CV-1887 (DMC), 2007 WL 2669338 at *1, *8 (D. N.J. Sept. 6, 2007) (finding persuasive that "the 6-deoxy modification had proven to be several times more effective than any other substitutions. Thus, the 6-deoxy would have been one of the first options explored by one skilled in the art"). In addition, Dr. Rangayyan did not point to anything in the prior art, or the record developed during discovery, that demonstrated a likelihood of success in solving the problem of correcting local contrast based on the use of an adaptive gamma function. *See, e.g., Omegaflex, Inc. v. Parker-Hannifin Corp.*, 243 F. App'x 592, 595–97 (Fed. Cir. 2007).

Moreover, Dr. Rangayyan's statement in the last sentence of paragraph 133 of his report does not solve the deficiencies with respect to the missing aspects of his analysis. The sentence states: "[f]or example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good

reason to pursue the known options within his or her technical grasp." (Exhibit A, Rangayyan Report at ¶ 133). Although this statement parrots language from *KSR* (*KSR*, 127 S. Ct. at 1742 ("When there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp.")), Dr. Rangayyan did not state (even conclusorily) that there is a design need or market pressure and a finite number of solutions *in this case*. Moreover, the parroted portion of *KSR* requires more: "*If* this leads to the anticipated success, it is likely the product not of innovation but of ordinary skill and common sense. In that instance the fact that a combination was obvious to try *might* show that it was obvious under § 103." *Id*. (emphasis added). And, importantly, *KSR* only states that under such circumstances it "*might*" show obviousness. Consequently, the parroted language is again not determinative and is therefore insufficient to establish obviousness.

Nor did Dr. Rangayyan fix his flawed analysis during his deposition. In fact, he admitted that he did not provide, and does not have, an opinion as to a reason to combine the prior art. He testified that he "cannot say what the aim or purpose of that could possibly be."

> Q. Did you provide an opinion or did you reach a conclusion as to why one of skill in the art would combine the teachings of Sabri with those found in the Gonzales algorithm?
>
> A. That could be left open. It depends upon the end goal of the person who would put multiple methods together. Depending upon the combination employed of the multiple methods, the end result could be different.
>
> So I cannot say what the aim or purpose of that could possibly be. Different results could be achieved.

(Exhibit B, Rangayyan Dep. Tr. at p. 252, lines 14–24.) *KSR* simply does not permit an accused infringer to leave the reason to combine "left open." Dr. Rangayyan must have either articulated the reason to combine the references, or pointed to something in the record, that showed the

motivation to combine the references before reaching his opinions on obviousness. *See Innogenetics, N.V.*, 512 F.3d at 1374 ("[A]s the district court held, 'some kind of motivation must be shown from some source, so that the jury can understand why a person of ordinary skill would have thought of either combining two or more references or modifying one to achieve the patented method.'") (citation omitted).

Based on the applicable legal standard set forth in *KSR*, and applied in *PharmaStem* and *Takeda Pharmaceutical*, Dr. Rangayyan failed to conduct a proper obviousness analysis. It simply is not enough for one to compare the claims with the prior art. As explained in *Innogenetics*, *PharmaStem* and *Takeda Pharmaceuticals*, an expert must also show, or rely on evidence in the record establishing, that a person of ordinary skill in the art would have had a reason to combine the prior art and that such a person would have had a reasonable expectation of success in doing so. *Id.*; *PharmaStem Therapeutics, Inc.*, 491 F.3d at 1360; *Takeda Pharm.*, 2008 WL 839720, at *12. Dr. Rangayyan did not do so.

(b) Because He Did Not Apply A Proper Methodology, Dr. Rangayyan Should Be Precluded From Offering His Obviousness Opinions.

The Supreme Court has "assign[ed] to the trial judge the task of ensuring that an expert's testimony both rests on a reliable foundation and is relevant to the task at hand." *Daubert v. Merrell Dow Pharms., Inc.*, 509 U.S. 579, 597 (1993); *see also Izumi Prods. Co. v. Koninklijke Philips Elecs. N.V.*, 315 F. Supp. 2d 589, 600 (D. Del. 2004). The standard for deciding whether an expert's testimony is relevant and reliable arises from Federal Rule of Evidence 702, which provides:

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable

> principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.

FED. R. EVID. 702. As part of this analysis, the court must determine whether the purported expert's testimony will assist the trier of fact. *Izumi Products*, 315 F. Supp. 2d at 601.

The Third Circuit has interpreted Rule 702 to include "three distinct substantive restrictions on the admission of expert testimony: qualifications, reliability, and fit." *Id.* at 600 (quoting *Elcock v. Kmart Corp.*, 233 F.3d 734, 741 (3d. Cir. 1998)). An expert's opinion is considered to be reliable if it is based on valid scientific knowledge. *Daubert*, 509 U.S. at 589–90. However, expert opinions are inadmissible if they are the product of unreliable principles and methods. *See* FED. R. EVID.702 advisory committee's note; *Daubert*, 509 U.S. at 591–95. Expert opinions are also inadmissible if they are based upon speculation or are not properly grounded in scientific principle. *See* FED. R. EVID. 702 advisory committee's note ("The trial judge in all cases of proffered expert testimony must find that it is properly grounded, well-reasoned, and not speculative before it can be admitted.") Moreover, if an expert applies an incorrect legal standard, it should be excluded because it is not helpful and may instead confuse or mislead the jury. *See KB Home v. Antares Homes, Ltd.*, Civil Action No. 3-04-CV-1031-L, 2007 WL 1893370, at *1, *9–10 (N.D. Tex. June 28, 2007) (where the court and magistrate judge took issue with the expert witness for failing to apply the correct legal standard, and the magistrate judge further explained that "testimony that relies on an incorrect legal standard would 'confuse and mislead the jury'"); *see also Trueposition, Inc.*, 2007 WL 2429415, at *1 (precluding expert from testifying where he failed to set forth the proper invalidity analysis); *see also Trueposition, Inc. v. Andrew Corp.*, Civ. No. 05-747-SLR, Summ. J. Mem. Op. at 17 (D. Del. Aug. 23, 2007) (where court subsequently granted summary judgment on defendant's invalidity defense). Here, Dr. Rangayyan did not conduct the proper analysis required by the

legal standard for obviousness, and his opinion should therefore be excluded. *See Innogenetics, N.V.*, 512 F.3d at 1374 (holding that the district court did not err in precluding expert's "vague and conclusory obviousness testimony which did not offer any motivation for one skilled in the art to combine the particular references he cites in order to practice the claimed method"). Specifically, Dr. Rangayyan did not set forth a reason to combine the prior art references, and he did not explain why one of ordinary skill in the art would have had a reasonable expectation of success in doing so.

Because the method used by Dr. Rangayyan to conclude that the claims of the '381 patent are invalid on the grounds of obviousness is unreliable, his opinion is inadmissible. *Daubert*, 509 U.S. at 591–95. Moreover, Dr. Rangayyan's incomplete analysis will not be helpful, and indeed would be misleading, to a trier of fact. *Izumi Products*, 315 F. Supp. 2d at 601. As a result, Dr. Rangayyan should not be allowed to offer his opinions on obviousness.

III. CONCLUSION

Dr. Rangayyan's opinions concerning the alleged obviousness of Polaroid's '381 patent should be excluded.

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/s/ Julia Heaney

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LOCAL RULE 7.1.1 STATEMENT

Pursuant to Local Rule 7.1.1, counsel for Polaroid made a reasonable effort to reach agreement with opposing counsel on the matters set forth in this motion.

/s/ Julia Heaney

Julia Heaney (#3052)

CERTIFICATE OF SERVICE

I, the undersigned, hereby certify that on May 23, 2008, I electronically filed the foregoing with the Clerk of the Court using CM/ECF, which will send notification of such filing(s) to the following:

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I also certify that copies were caused to be served on May 23, 2008 upon the following in the manner indicated:

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EXHIBIT A

IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

POLAROID CORPORATION, Plaintiff, v. HEWLETT-PACKARD COMPANY, Defendant.	)	C.A. No. 06-783 (SLR)

EXPERT REPORT OF DR. RANGARAJ RANGAYYAN

I, Dr. Rangaraj Rangayyan, submit this report on behalf of the defendant Hewlett-Packard Company ("HP").

I. INTRODUCTION

1. I am a full professor in the Department of Electrical and Computer Engineering at the University of Calgary, which is in Calgary, Alberta, Canada ("UofC"). I am also an adjunct professor in the Departments of Surgery and Radiology at UofC. I have been a professor in the Department of Electrical and Computer Engineering at UofC since 1984.

2. I have been elected as a Fellow of the following professional organizations: Institute of Electrical and Electronics Engineers (2001), Engineering Institute of Canada (2002), American Institute for Medical and Biological Engineering (2003), the International Society for Optical Engineering (2003), Society for Imaging Informatics in Medicine (2007) and the Canadian Medical and Biological Engineering Society (2007). I am also a registered Professional Engineer in the Province of Alberta, Canada.

3. I hold a Bachelor of Engineering (B.E.) in Electronics and Communication from the University of Mysore, Mysore, India (1977). In 1980 I was awarded a Ph.D. degree in Electrical Engineering from the Indian Institute of Science, Bangalore, India. While a graduate student at the Indian Institute of Science, I began my studies and research on digital image processing. My Ph.D. dissertation focused on digital signal processing techniques for computerized analysis of biomedical signals, such as the electrocardiogram (ECG) and heart sounds.

4. Prior to joining the faculty at UofC in 1984, I was an assistant professor in the Department of Electrical Engineering at the University of Manitoba in Winnipeg, Canada ("UMan"). I was also a systems analyst in the Department of Pathology at UMan. While at UMan, I conducted research on adaptive contrast enhancement techniques for digital signal and image processing and on contrast enhancement of mammograms, which are X-ray images of the breast.

5. In 1982, as an assistant professor at UMan, I developed a new graduate-level course on digital image processing. When I moved to UofC in 1984, I established a course directed to the same subject matter at UofC. Collectively, I have taught a graduate-level course on digital image processing for the last twenty-five years.

6. I have supervised dozens of graduate and undergraduate students on thesis-oriented research work. Several of these projects were directed towards the development of image processing and contrast enhancement techniques.

7. I have given many lectures, research seminars, and tutorials on digital image processing, medical imaging and image analysis, biomedical signal analysis, and related topics. I have also collaborated with researchers at universities, institutes, and research organizations in

India, Canada, the United States, Brazil, Argentina, Uruguay, Chile, the United Kingdom, Russia, The Netherlands, Egypt, France, Spain, Italy, Romania, Malaysia, Singapore, Thailand, Japan, Hong Kong, and China.

8. Because of my expertise in image and signal processing, I have held, or currently hold, Visiting or Adjunct Professorships at: University of Liverpool, Liverpool, UK (2006-current); Tampere University of Technology, Tampere, Finland (1998, 1999, 2007); Universitatea Politehnica Bucureşti, Bucharest, Romania (1996, 1997, 1998); Universidade de São Paulo, São Paulo, Brasil (1994-95); Cleveland Clinic Foundation, Cleveland, Ohio, USA (1999); Indian Institute of Science, Bangalore, India (1988, 1994); Manipal Institute of Technology, Manipal, India (2006-current); Beijing University of Posts and Telecommunications, Beijing, China (2006-current); and École Nationale Supérieure des Télécommunications de Bretagne, Brest, France (1995, 1999).

9. I have authored over 300 journal papers and conference publications, most of which are directed to image processing, and many of which are directed specifically to contrast enhancement in digital images.

10. I am the author of the following university-level textbooks directed towards image and signal processing: “Biomedical Signal Analysis” (IEEE Press and Wiley, New York, NY, 2002); and “Biomedical Image Analysis” (CRC Press, Boca Raton, FL, 2005).

11. A full list of my research, publications, awards and recognitions are provided with my curriculum vitae, a copy of which is attached as Appendix A.

12. I have conducted research on, and developed, several algorithms for biomedical signal and image processing applications. One of the major applications on which I have worked is the analysis and contrast enhancement of mammograms for computer-aided diagnosis of breast

cancer. Methods that I developed for contrast enhancement in mammograms have allowed radiologists to differentiate more accurately between malignant and non-malignant disease of the breast, leading to earlier detection of breast cancer.

13. I have been asked to serve as an expert witness in this litigation. Prior to my engagement, I had never consulted to Choate, Hall & Stewart, LLP, Fish and Richardson P.C., or HP. I have not previously been retained as an expert witness in any litigation. I have been, and expect to be, compensated for these services at my customary consulting rate of $300.00 per hour. My compensation for these services is not contingent upon the outcome of this action.

14. I have been asked to review U.S. Patent No. 4,829, 381 ("the '381 patent") and assess the validity of the '381 patent.

15. In rendering my opinion, I have reviewed the documents and materials attached to or described in Exhibit B. In particular, I have read the '381 patent, its file history, the cited references and the prior art references identified in this report. I have also reviewed the claim constructions proposed by HP and by Polaroid.

16. I understand that fact discovery in this matter is closed. However, I have been told that some discovery material may not be available until after the date of this report. Therefore, I may supplement this report as necessary or appropriate in view of further discovery or other events, including any ruling by the Court that is pertinent to my analysis. In addition, if requested, I may supplement this report and/or testify at trial in response to evidence put forward, or expert testimony advanced, by Polaroid.

17. The objective of my investigation was to assess whether that which is claimed in the '381 patent was novel and not obvious, as those terms have been explained to me, in view of

the art that existed at the time the ‘381 patent was filed. I carried out this investigation personally.

18. It is my opinion that the invention claimed in the ‘381 patent is either not novel or is obvious, as those terms have been explained to me, in view of the art that existed at the time the ‘381 patent was filed.

19. I may use the exhibits to this report and any referenced documents and information to support testimony concerning the ‘381 patent, the state of the art of image processing and the subject matter of my investigation. In addition, I may use any diagrams, aids or other presentation materials to illustrate my analysis of the ‘381 patent or any other technology described in this report.

II. BACKGROUND

A. Digital Image Processing

20. At trial, I may be asked to testify about, and explain, the fundamentals of digital image processing. In brief, an image is a visual representation of a person, an object or a scene that is produced or displayed on a surface, such as paper. For example, a photograph produced by a camera provides a visual representation, or image of the scene which the camera captured. The photograph is considered a human-readable format of the image.

21. A digital version of the image, or digital image, is the image stored as numerical values in an electronic device, such as a computer. The numerical values are the computer-readable version of the human-readable image. For example, a photograph scanned into a computer is converted from its human-readable format of the photograph to a computer-readable digital format.

22. In computer-readable format, a digital image is made up of a fixed number of rows and columns. Each intersection point of the rows and columns is represented by a value.

Each value is a numerical representation of an element of the picture at that point. This picture element is often referred to as a "pixel." Thus, a digital image having 256 rows and 256 columns would be represented by a total of 256 x 256, or 65,536, pixels.

23. In a digital image the values for a pixel have a fixed range of values. The range is limited by the number of bits used to express each pixel value. The larger the number of bits used to store a value, the greater the number of different values that may be stored. Conversely, the smaller the number of bits used to store values, the smaller the number of different values that may be stored.

24. In a rudimentary example, each pixel might be represented by a one bit value. That is, each pixel would be represented by either a "1" or a "0." In this form, one of the pixel values indicates that the pixel is "on" and the other indicates that the pixel is "off." Using this system, a digital image may be represented as a collection of black pixels and white pixels.

25. Using more bits to represent each pixel allows a pixel in a black-and-white image to represent shades of gray. If each pixel value were represented by a 4-bit value, then each pixel could have one of a possible 16 values, for example, 16 shades of gray ranging from "white" to "black." This simple example illustrates the concept of "luminance," that is, the brightness of an image. In an image in which each pixel is one of 16 shades of gray (commonly referred to as a "grayscale image"), each pixel value represents the brightness, or luminance, of the image at that point. The tiny area of the image represented by a pixel may itself have a range of luminance values. A pixel, therefore, represents the average luminance for the area of the image to which it corresponds.

26. The concept of luminance is not restricted to grayscale images. In the example immediately above, each pixel value could represent 16 shades of another color ranging from

black to the other color. The difference between the maximum value that a pixel may have and the minimum value that a pixel may have is referred to as the "dynamic range." In the four-bit example, the color ranges from "0000" (very dark) to "1111" (very bright)," and the dynamic range is 0 (0000) to 15 (1111).

27. An inherent element of digital images is that pixels have a discrete number of brightness levels within the dynamic range. In the four-bit example, there are sixteen levels. However, images in the real world are not limited to an arbitrary number of brightness levels that are represented by a fixed number of bits in a digital image. For example, an outdoor scene may contain areas with bright sunlight and dark shadow and many different gradations in between (indeed, there are potentially an infinite number of brightness levels in the scene itself). The number of gradation levels may very well exceed the number of discrete brightness levels afforded by a digital system.

28. When a digital imaging device attempts to represent a real-world scene, it must do so using only values that exist within its dynamic range. If the actual number of degrees of brightness of the real-world scene is greater than the number of brightness levels the device can represent using its dynamic range (as is typically the case), the imaging device must attempt to represent the actual variations of the image within the values that are available to it. That is, there are only a limited number of values to assign to a pixel to try to account for the infinite number of brightness levels in the actual scene.

29. A digital image may be modified using digital image processing, which is the use of a device that "reads" an input image and, through a series of steps, produces an output image with desired properties. These steps may be referred to as routines, which collectively may be referred to as a process or a method. The process of changing the properties of a digital image

may be referred to as transformation. Changes to the size, resolution or color of an image are types of transformations.

30. Transformation of digital images via digital image processing may be used to improve the quality of the image. The transformation may include one or more enhancement functions, techniques or algorithms to process an image so that the resulting digital image is more suitable than the original image. A transformation changes the original pixel values of a digital image to different pixel values in the processed output image. A transformation function may be applied to one pixel at a time (i.e., on a pixel-by-pixel basis), or to groups of pixels. Many of these transformations are directed to dealing with the challenges of representing the wide dynamic range of brightness in a real-world scene using the fixed dynamic range available for a digital image.

31. One type of transformation that may be applied to a digital image is "contrast enhancement," which may also be referred to as "gamma correction" by those skilled in the art. Contrast enhancement attempts to increase the difference in appearance between adjacent pixels or groups of pixels in an image. This is accomplished by increasing the difference between the value of a single pixel and the value of pixels in an area adjacent to that pixel.

32. The amount by which an input pixel value is changed when transforming an image may be effected by a linear transformation function or nonlinear transformation function. A linear transformation function changes each input pixel value to a new output pixel value by the same factor for all the pixels that make up an image. That is, each output pixel value is directly proportional to the corresponding input pixel value. A nonlinear transformation function changes input pixel values to output pixel values by different factors at different points in the digital image. For example, when a nonlinear transformation function is used, a first input pixel

may be changed to an output pixel value by a factor of 0.5, whereas a second input pixel may be changed to an output pixel by a factor of 2.

33. Local area contrast enhancement may be performed by increasing the difference between a single pixel's value and the average value of pixels in an area adjacent to that pixel. The group of pixels in the area adjacent to the subject pixel is referred to as a neighborhood or window. The average value of the neighboring pixels may be determined by adding the values of a group of pixels in the neighborhood, or local area, of the subject pixel and dividing by the number of pixels in the neighboring area. A local contrast measure may be determined by taking the difference between the value of the subject pixel and the average value of the pixels in the local area. Local contrast enhancement may change the value of the subject pixel as compared to the average value of the pixels in the neighborhood of the pixel, so as to increase the difference in appearance between them.

B. State of the Art in Digital Image Processing Prior to the ‘381 Patent

34. Techniques for transforming digital images have been known for decades. For example, the Jet Propulsion Laboratory (“JPL”) was assigned the task of improving the quality of transmitted images of Apollo 11 landing on the Moon in 1969. JPL conducted research and developed several transformation and contrast enhancement techniques to improve the quality of digital images.

35. During the 1970s and 1980s there was wide recognition of the desirability of improving digital output images so as to increase the contrast within areas of an image and thus make details in the image more visible to human observers. A variety of techniques were developed that addressed this problem. As will be apparent from the rest of this report, many of

these techniques include the same or similar components and many of the components of particular techniques were similar to the components of these image techniques.

36. When I developed my graduate-level course on digital image processing in 1982, I used three texts that specifically summarized a number of digital image processing techniques and which I discuss later in this report: (1) "Digital Image Processing", by Gonzalez R.C. and Wintz P., (Addison-Wesley, Reading, MA, 1977) ("Gonzalez"); (2) "Computer Image Processing and Recognition", by Hall E.L., (Academic, New York, NY, 1979) ("Hall"); and (3) "Digital Picture Processing", by Rosenfeld A. and Kak A., (Academic, San Diego, CA, Vol. 1-2, 1982) (Rosenfeld").

The Gonzalez and Hall Textbooks

37. The Gonzalez textbook was published in 1977. It includes many then well-known image enhancement techniques developed prior to 1977. (See Gonzalez, Chapters 3 and 4). The Hall textbook was published in 1979. It describes many then well-known image enhancement techniques developed prior to 1979. (See Hall, Chapters 3 and 4). Many of the techniques published in the Gonzalez textbook and the Hall textbook were taught to university students throughout the late 1970s and 1980s.

38. The Gonzalez textbook, in its Appendix A, includes a software algorithm that receives a digital image and prints it on a printer. The printer had a dynamic range from 0 to 31; that is, the line printer was capable of representing only 32 shades of gray. The algorithm in Gonzalez accepted images having a different dynamic range from that of the line printer. In such a situation, the input values of two adjacent pixels may be similar even though each pixel represented a part of the real-world image that was actually different. Therefore, the Gonzalez algorithm taught a technique for modifying the values of the pixels that made up the input image

so as to enhance the contrast between individual pixels and thus to improve the image generated by the printer.

39. The Hall textbook describes systems and methods for transforming pixel values that collectively define an image. (Hall, Section 3.2).

40. Hall described pixels as having values within a range of possible values determined by the number of bits used to represent each pixel value (Hall, Section 3.2.2 on quantization and Fig 3.1.3 illustrating images using different number of bits per pixel).

41. The Hall textbook taught, as early as 1979, that the contrast between a pixel and its surrounding area could be calculated by comparing the luminance value of the subject pixel to the average luminance value of the pixels in its immediate surrounding area. (See Hall, p. 27).

42. Hall dedicated an entire chapter to image enhancement. That chapter included a 27-page section describing multiple methods for performing contrast enhancement (Hall, pages 159-185).

43. Hall stated that "contrast generally refers to a difference in luminance or gray level values in some particular region of an image…." (Hall, p. 159).

44. Hall described measuring contrast as the ratio of the difference in luminance of an object, B_0, and the luminance of its immediate surround, B, to the luminance of the immediate surround, B.

$$C = (B_0 - B)/B$$

(Hall, p. 27).

45. Hall demonstrates that, as of 1979, it was well-known to use a neighborhood of pixels (e.g., a pixel and its eight immediate neighbors or, alternatively, a pixel's eight immediate

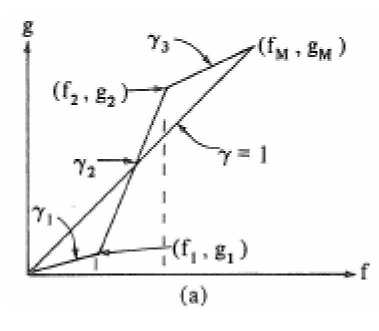
neighbors) to process digital images. (Hall. p. 205). Figure 4.32 on page 206 of Hall illustrated two possible neighborhoods, or groups of pixels, that could be used when processing the image.

46. Hall stated that pixel values may be altered to change the contrast between individual pixels using a linear or a nonlinear transformation. Hall further described performing a transfer, or mapping, function *T* on each input pixel value *f(x,y)* to provide an output pixel value *g(x,y)*. (Hall, p. 160,).[1]

47. Hall demonstrates that, in 1979, it was well-known to use, for contrast enhancement, a transformation function having multiple parts, each transforming an input pixel value by a different amount. (Hall, pages 163-164). The amount by which an input pixel value was changed was selected as a function of the value of the pixel being processed. (Hall, p. 164)

48. The transformation function described by Hall on pp. 163-4 states that an output pixel value, *g,* is based on the value of the input pixel. The input pixel value *f* has a value that ranges from 0 to the maximum input pixel value, f_m. The particulars of the transformation function show below are described in the next three paragraphs.

$$g = \begin{cases} \gamma_1 f + b_1; & 0 \le f < f_1; \quad \gamma_1 = g_1/f_1, \quad b_1 = 0, \\ \gamma_2 f + b_2; & f_1 \le f < f_2; \quad \gamma_2 = \dfrac{g_2 - g_1}{f_2 - f_1}, \quad b_2 = g_1 - f_1\gamma_2, \\ \gamma_3 f + b_3; & f_2 \le f \le f_M; \quad \gamma_3 = \dfrac{g_M - g_2}{f_M - f_2}, \quad b_3 = g_2 - f_2\gamma_3. \end{cases}$$



(See Hall, Fig 4.5, p. 159).

[1] In this expression, *x* and *y* represent the location of a pixel in an image and f*(x,y)* represents the value expressed by the pixel at the location *(x,y).*

49. For input pixel values greater than 0 and less than a predetermined value, f_1, Hall taught that an output pixel value is calculated using the following mathematical function: $g(x,y) = (g_1/f_1)f(x,y)+ b_1$. The ratio of g_1/f_1 is the slope of the line defining the transformation function for the range of input values between 0 and f_1. The calculation of g_1 times $f(x,y)$ is a calculated intermediate value, i.e., it is a value that is calculated after receiving the input values but before calculating the final output value, and the value f_1 is a value that falls within a range of possible input pixel values; that is, f_1 is a value that falls within the dynamic range of input pixel values.

50. For input pixel values greater than f_1 and less than a predetermined value, f_2, Hall taught that an output pixel value is calculated using a second mathematical function : $g(x,y) = ((g_2 - g_1/(f_2 - f_1))f(x,y) + b_2$. The ratio of $(g_2 - g_1/(f_2 - f_1)$ is the slope of the line defining the transformation function for the range of input values between f_1 and f_2. The calculation $g_2 - g_1$ times $f(x,y)$ is a calculated intermediate value and the value $f_2 - f_1$ is a value that falls within a range of possible input pixel values; that is, $f_2 - f_1$ is a value that falls within the dynamic range of input pixel values.

51. For input pixel values greater than f_2 and less than the maximum value of an input pixel, f_m, Hall explained that an output pixel value is calculated using a third mathematical function: $g(x,y) = ((g_m - g_2/(f_m - f_2))f(x,y) + b_3$. The ratio of $(g_m - g_2)/(f_m - f_2)$ is the slope of the line defining the transformation function for the range of input values between f_2 and f_m. The calculation $g_m - g_2$ times $f(x,y)$ is a calculated intermediate value and the value $f_m - f_2$ is a value that falls within a range of possible input pixel values, that is, $f_m - f_2$ is a value that falls within the dynamic range of input pixel values.

52. The transformation function described above is known as a "piecewise linear" function because it is made of three linear pieces. Each piece modifies an input pixel value by a

different factor. Hall also taught that a mathematical function that is not piecewise linear but has a nonlinear characteristic, such as a logarithm function or an exponential function, could be used for contrast enhancement. (Hall, pages 165-166).

53. The Hall and Gonzalez textbooks show that many of the elements claimed as new by the '381 patent were, in fact, well-known a decade before the application for the '381 patent was filed. Although I cite specific sections of the Hall and Gonzalez textbooks in this report, those textbooks reflect common knowledge at the time the application for the '381 patent was filed. I may, therefore, rely generally on those texts to support my testimony.

The Lee Publication

54. Another example of well-known techniques for contrast enhancement from this same time period is the article titled, "Digital Image Enhancement and Noise Filtering by Use of Local Statistics," by Jong-Sen Lee, (IEEE Transactions on Pattern Analysis and Machine Intelligence, Vol. PAMI-2, No. 2, pp. 162-168, March 1980) ("Lee").

55. The method taught in Lee for contrast enhancement is similar to a method originally proposed by Wallis in 1976. (Lee, p. 165, col. 2). The method proposed by Wallis was well-known in the literature on digital image processing in the 1970s and 1980s, as indicated by the description and illustrations of the method in the textbook by Pratt (1978) on pages 325 and 326.

56. Lee described systems and methods for transforming in succession a series of input pixel values that collectively define an image. (Lee, col. 1, Abstract). Lee stated that "each pixel is processed independently." (Id.).

57. Lee described pixel values having a value within a dynamic range of values (Lee, p. 166, last paragraph). Lee described grayscale images in which pixels have values between 0 and 255. (Id.).

58. Lee described methods for computing local statistics such as the average luminance of a selected group of pixels around the pixel being processed (the "mean" luminance value) and determining the amount by which the luminance of an individual pixel varied from the average of the luminance of the pixels in its vicinity. Lee does this to enhance image contrast in a selective manner. (Lee, p. 165, col. 2, lines 48-55).

59. Lee explained that the neighborhood or window used to obtain the selected group of pixels could be of different sizes, such as 3×3, 5×5 and 7×7. (Lee, p. 166, col. 1, paragraph after Eq. 5).

60. Lee provided two equations that can be used to calculate average pixel values of a selected group of pixels in a neighborhood. (See Eq. 1 and 2, Lee). The first average value taught by Lee, $m_{i,j}$, is the arithmetic mean of a selected group of pixel values, including the pixel being processed. The mean, by definition, has a value within the dynamic range of the pixel values being averaged. The second average value taught by Lee, $v_{i,j}$, is the variance, in which the squared variation of each pixel value from the average pixel value for the selected group of pixels is averaged. Variance is also a measure of contrast.

61. Lee taught one other local statistic that can be used for contrast enhancement, which is the standard deviation. The standard deviation is the square root of the variance, v_{ij}, which is a measure of the variance of the pixel values from the average value of the pixel values.

62. Lee described how local statistics may be used to achieve contrast enhancement. (Lee, Eq. 3). Lee teaches that a new output pixel value may be calculated by determining the

difference between the input pixel value and the mean value of its neighborhood of pixels. The difference is multiplied by a "gain" factor, *k*. The mean value of the neighborhood of pixels is then added to the results.

63. Thus, Lee shows that local area statistics can be used to selectively enhance the contrast of a digital image.

<u>The Narendra publication</u>

64. In 1981, the article "Real-Time Adaptive Contrast Enhancement", by Patrenahalli M. Narendra and Robert C, Fitch (IEEE Transaction on Pattern Analysis and Machine Intelligence, VOL. PAMI-3, No. 6, pp. 655-661, November 1981 ("Narendra")) was published.

65. Narendra described systems and methods for improving an image by transforming pixel values received as a series of pixel values that collectively define an image. (Narendra, Abstract, Introduction, first paragraph, and Fig. 8).

66. Narendra explained that pixel values are within a dynamic range of values. (Narendra, p. 656, Section 11, first paragraph, and Fig. 1).

67. Narendra described a local contrast enhancement scheme and various computations of local area statistics. (Narendra, p. 656, col. 1, paragraph 3).

68. Narendra said that "the local contrast can be enhanced (by increasing the local gain) without exceeding the dynamic range of the display." (Narendra, p. 656, col. 1, paragraph 5).

69. Narendra explained that the "image intensity [i.e., image luminance] at each point is transformed based on local area statistics – the local mean M_{ij} and the local standard deviation σ_{ij}" computed on a local area surrounding the point" (Narendra, p. 656, col. 2, paragraph 2).

70. Narendra described transforming the input pixel to an enhanced value by subtracting the local mean from the input pixel value, multiplying that amount by a gain factor, $G_{i,j}$, and adding the local mean to the result. The gain factor, $G_{i,j}$, is a ratio of a global mean pixel value to the local standard deviation, σ_{ij}, multiplied by a constant. (Id.) By definition, the standard deviation, as depicted in FIG. 2 of Narendra, is a value that lies within a possible range of values provided by the dynamic range.

71. Narendra illustrated a local area contrast enhancement algorithm, including the above described calculations in FIG. 2 on page 657.

72. Narendra illustrated the implementation in circuitry of their local area contrast enhancement algorithm in Figures 4-6 on page 658.

73. Narendra, like Lee, showed that local area statistics may be used to selectively enhance contrast in a digital image. Narendra also taught that, as early as 1981, it was easy for an algorithm to be constructed as a circuit.

The Wang publication

74. In 1983, the survey article titled, “Digital Image Enhancement: A Survey”, by David C. Wang, Anthony H. Vagnucci and C.C. Li, (Computer Vision, Graphics, and Image Processing, Vol. 24, pp 363-381 (1983)) (“Wang”) was published.

75. In the abstract, Wang stated that “Over decades, many image-enhancement techniques have been proposed” and “many of these techniques have been implemented.” (Abstract, Wang). Wang provided a survey of several techniques for image enhancement. Wang teaches several formulas and methods for rescaling gray levels to achieve contrast enhancement using a wide variety of functions.

76. Wang described systems and methods for enhancing pixel values received as a series of pixel values that collectively define an image. (Wang, p. 363, Introduction, first paragraph, Fig. 1-1).

77. Wang described pixel values having a value within a dynamic range of values (See Wang, p. 363, Notations, "g_{max} is the maximum gray level of the observed image" and "g_{min} is the minimum gray level of the observed image.").

78. Wang described computing an average of the values of a neighborhood of a pixels being processed (See Wang, p. 367, Eqs. (4-1) and (4-2),). "In (4-1), the gray level at *(x, y)* is replaced by the gray level average over a . . . rectangular neighborhood surrounding *(x, y)*." (Id.).

79. Wang presented several linear and nonlinear transformation functions useful for image enhancement (See Wang, p. 372, Figure 5-1). Wang further illustrated in Equations (5-2) and (5-3) several methods to obtain nonlinear transformation functions. The last formula in Equation 5-3 shows a ratio, g_{max}/g_{min}, raised to a power of $P(g(x,y))$ where g_{max} is the maximum value for a pixel, g_{min} is the minimum value of a pixel and $P(g(x,y))$ is a function that varies over the range 0 to 1. After being raised to the power of $P(g(x,y)$, the result is multiplied by $g_{min.}$

80. Another formula in Equation (5-3) facilitates the selection of a different transformation for each pixel depending upon its value. (See p. 373, Wang). The formula has two stages of nonlinearity, including the calculation of $P(g(x,y))$ and its use as the power factor applied to the ratio g_{max}/g_{min}.

81. As a survey article, Wang shows that different techniques for image processing use similar constituent parts to achieve contrast enhancement and that those parts are often used, or are attempted to be used, interchangeably. Although I cite specific sections of Wang in this report, those textbooks reflect common knowledge at the time the application for the '381 patent

was filed. I may, therefore, rely generally on Wang to support my testimony.

The Rangayyan publication

82. In 1984, I co-authored "Feature Enhancement of Film Mammograms using Fixed and Adaptive Neighborhoods", by Gordon R and Rangayyan RM, Applied Optics, 1984, 23(4): 560-564 ("Rangayyan"). My paper described a method in which "a pixel operator is applied to the image which performs contrast enhancement according to a specified function." (Rangayyan, p. 560, col. 1, lines 22-24). The method described in my paper performs adaptive contrast enhancement, a process by which a different transformation function is selected for each input pixel.

83. My paper described systems and methods for enhancing pixel values received as a series of pixel values that collectively define an image. (See Rangayyan, Section A, Image Acquisition).

84. My paper also described pixel values having a value within a dynamic range of values (See Rangayyan, Section B, Contrast Enhancement, stating "the display range of 0 to 255.").

85. My paper stated that contrast for a pixel is measured as $C = |p-a| / (p+a)$, where p is the value of the pixel being processed and a is the average value of the eight pixels in the immediate vicinity (the 3×3 neighborhood) (see Rangayyan, p. 561, col. 1, ll. 36-40). It further described how the values of p and a are computed using adaptive neighborhoods of different sizes, such as 3×3, 5×5, 9×9 and 15×15. (Rangayyan, p. 561, col. 2. ll. 15-31; see also Figure 1 on p. 561).

86. My paper described a method of increasing the contrast measured, as above, by using a nonlinear mathematical function. It further explains that this function may be varied or

selected as desired. (see Rangayyan, p. 561, col. 1, ll. 36-40, stating "[t]he contrast value is now enhanced according to a specified function to a new value *C'*. A simple enhancement function is $C' = \sqrt{C}$..." .)

87. My paper also described the selection of a transfer function for each pixel being processed as a function of the average value of the selected group of pixels and the value of the pixel being processed. (see Rangayyan, Section B, Contrast Enhancement, 2nd paragraph). The value of the pixel currently being processed is modified by providing a new pixel value from a function selected based on the average value of the pixels near the subject pixel and the value of the subject pixel:

$$p' = a(1 + C')/(1-C') \text{ if } p >= a$$

$$p' = a(1-C')/(1 + C') \text{ if } p < a \quad \text{(Id.)}$$

88. Furthermore, my paper explained how the means and methods described above may be used to achieve adaptive contrast enhancement so as to improve the visibility of objects in images in dark areas as well as in light areas of an image. Examples of results of the application of the methods are given with X-ray images of the breast (mammograms).

89. Rangayyan taught that the size of the neighborhood used to help determine the new pixel value could be itself adaptive.

<u>The Sabri Patent</u>

90. On December 3, 1982, the application for U.S. Patent No. 4,528,584 was filed. The patent was issued on July 9, 1985, and names Mohammed S. Sabri ("Sabri") as the inventor.

91. Sabri described systems and methods for enhancing successively received pixel values that collectively define an image. (see Sabri, col. 3, ll. 18-30, and Figs. 1 and 2).

92. Sabri described pixel values having a value within a dynamic range of values (see Sabri, col. 3, ll. 19-22, "the input signal is in digital form, for example, 8 bits").

93. Sabri described averaging a selected group of pixels around a subject pixel to provide an average according to the formula:

$$\phi_{ij} = \sum_{n=0}^{N_1} \sum_{m=0}^{N_2} a_{nm} X_{i-n,j-m}$$

(Sabri, col. 3, ll 1-4 and 40-45,).

94. Sabri further described deriving from multiple pixels a first signal proportional to the luminance component of the input signal as a computed intermediate value in the form of an average. (Sabri, col. 2, ll. 7-9,). The signal proportional to the luminance component is computed as an average (Φij) of pixel values in an (N_1+1) x (N_2+1) matrix.(Sabri, col. 4, lines 44-46). The input pixel X_{ij} is an element of the matrix and used in computing the average (Sabri, col. 4, lines 46-49).

95. Sabri described determining a level of contrast enhancement as a factor of gamma, γ_{ij} as function of a ratio of the average (Φij) as a numerator over a denominator of the maximum of the dynamic range of the signal R, for example 256 for an 8-bit digital system. (Sabri, col. 4 ll. 26-35).

96. Sabri illustrated in FIG. 1 circuitry for selecting a transfer function as a function of the ratio of the intermediate calculated value - average Φij - and the pixel value currently being processed X_{nm} which also is used in computing the average Φij (see Sabri, elements 10, 12, 14 and 68, FIG. 1).

97. Sabri illustrated in FIG. 1 circuitry for selecting and transforming each input pixel being processed from the selected transfer function as a function of the ratio of an average Φij to the dynamic range R (see Sabri, elements 70, 66 and 68, FIG. 1).

98. Sabri described that the signals being processed may be analog or digital in performing contrast enhancement techniques. (Sabri, col. 3, lines 18-30).

99. Sabri taught a local contrast enhancement algorithm that uses the dynamic range in the denominator of a transfer function.

The Richard Patent

100. United States Patent No. 4,654,710 to Christian J. Richard ("Richard") was issued as a patent on March 31, 1987 based on an application filed on January 3, 1986.

101. Richard described a contrast amplifier for improving the quality of images. (see Richard, Field of the Invention).

102. Richard explained that it is "a known practice to enhance or amplify the contrast of video images by increasing the gain of transmitted luminance signals representing the images." (Richard, col. 1, lines 12-15).

103. Richard described systems and methods for continuously enhancing pixel values received as a successive series of pixel values that collectively define an image. (see col. 2, ll. 26-34, Richard, see Brief Description of the Drawings and Figure 1).

104. Richard described pixel values having a value within a dynamic range of values (see Richard, col. 3, ll. 33-47, col. 5, l. 66 – col. 6, l. 19, and Figure 1).

105. Richard described averaging a selected group of pixels to provide an average pixel value, such as the global mean or local mean. Richard describes "a means for estimating a mean value M_g of luminance of all points of each image in succession." (Richard, col. 1, lines

62-63). This refers to the global mean. Richard further describes "a means for computing a local mean value M_v of luminance of a point being processed." (Richard, col. 1, lines 62-63). This refers to the local mean.

106. Richard described "a means for multiplying the value of luminance of the point being processed by a variable coefficient which is proportional to the ratio M_v/M_g." (Richard, col. 1, lines 66-68). The ratio M_v/M_g has a numerator that is the average value of pixels, in a local region of the pixel being processed and a denominator that is a value in the range of possible values of the dynamic range (the global mean). The value M_v is both an average and an intermediate calculated value. The value M_g is both a value in a range of possible values and a value within the dynamic range.

107. Richard illustrates circuitry and devices that use the ratio M_v/M_g for performing contrast enhancement. Block 5 of the Figure includes circuit components for selecting a transfer function based on the input value Y_{ij} and an average M_g (see Richard, Figure 1, output from element 10). The circuitry transforms the value of the pixel being processed to an enhanced output value based on the selected transfer function and a ratio of an average value for a group of pixels adjacent to the subject pixel M_v over a value in the dynamic range, M_g, the global mean. (see Richard, Figure 1, output 13).

108. Richard explains that "the effect of the contrast amplifier is …to reduce the luminance of the current point in order to bring it close to the value of black or respectively to increase said luminance in order to bring it close to the value of pure white." (Richard, col. 5, l. 66 – col., 6, l. 3).

109. Richard described a circuit for local area contrast enhancement that calculates local mean values for groups of pixels and the use of a user-controllable constant for controlling the amount of gain applied to an image.

The Chen Patent

110. United States Patent No. 4, 789,933 to Chen et al. ("Chen") was issued on December 6, 1988 based on an application filed on February 27, 1987

111. Chen describes systems and methods for continuously enhancing pixel values received as a successive series of pixel values that collectively define an image. (see Chen, col. 1, l. 62 – col. 2 l. 3, col. 4, ll. 45-65 and Fig. 1).

112. Chen describes pixel values having a value within a dynamic range of values (see Chen, col. 1, l. 62 – col. 2, l. 3).

113. In the Abstract, Chen describes computing "the mean of pixel values of neighboring pixels" (Chen, Abstract).

114. Chen also describes, in the Abstract, selecting a transfer function uniquely defined for each pixel being processed and using the mean of pixel values of neighboring pixels. (Id.).

115. Chen describes "an image improvement means for replacing each pixel value by a weighted combination of the replaced pixel value and an average of the surrounding pixels." (Chen, col. 9, 11. 59-63).

116. Chen further describes processing and averaging selected groups of neighboring pixels in two rings that surround the pixel being processed (Chen, col. 6, ll.18-60 and col. 10, ll. 20-29; see also Figure 2). Chen describes computing a contrast-related measurement using a ratio of the average value of the difference between pixel values selected from the rings. (Id.) This ratio has an intermediate calculated value of a first average of the difference between pixel values as a numerator over a value that lies within the possible values of the dynamic range.

117. Chen further describes that the transfer function is derived from the ratio of comparing (i) a variation between the pixel value being processed and the average pixel value of pixels in the first ring to (ii) a variation between the pixel value being processed and the average pixel value of pixels in of the second ring. (Id.).

118. Chen describes transforming each pixel value with an improved pixel value using the transfer function and ratios described above. (Id.)

119. Chen teaches that, by 1987, the state of the art in digital image processing had advanced beyond "simple" statistical functions for local area contrast enhancement. Chen describes using multiple averages and fractals for local area contrast enhancement.

120. A list of the references I used in forming this Opinion is attached as Exhibit B.

121. In my digital image processing course taught to university students from 1983 to 1987, a typical student would learn and understand these digital image processing techniques. That is, the state of the art in digital image processing prior to the time of filing of the application for the '381 patent made it well-known: to sharpen an image or enhance the contrast of the image; to detect edges as part of contrast enhancement; to apply various mathematical transformations to determine an average of a selected group of pixels, including the pixel being processed; choose a gamma transfer function based on the average value of a neighborhood of pixels adjacent to the pixel being processed; use a ratio in a transformation function; and transform the pixel being processed based on the gamma value produced by the gamma transfer function.

122. In my opinion, in 1988 and 1989, in the context of the '381 patent, a person of ordinary skill in the art would typically have a Bachelor's degree in electrical engineering and two years of coursework or practical experience directed to digital signal or image processing.

III. THE '381 PATENT

123. The application for the '381 patent was filed on April 18, 1988. The '381 patent issued on May 9, 1989, and is titled, "System and Method for Electronic Image Enhancement by Dynamic Pixel Transformation." It names as inventors Woo-Jin Song and Donald S. Levinstone.

124. I have read, and understood, the '381 patent and its prosecution history. I have been asked to review claims 1-3 and 7-9 of the '381 patent.

125. Claims 1 and 7 of the '381 patent are "independent" claims. Claims 2 and 3 depend on claim 1. Claims 8 and 9 depend on claim 7.

126. As originally filed on April 18, 1988 claim 1 read:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:
>
> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged; and
>
> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel.

As originally filed, Claim 7 of the '381 patent, then numbered claim 8, read:

> A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal corresponding to one of a plurality of succeeding pixels which collectively define an image, said method comprising the steps of:

> averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;
>
> selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and
>
> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel.

127. On October 12, 1988, the Examiner rejected claims 1 and 8 as unpatentable over United States Patent No. 4,489,349 to Okada ("Okada"). The examiner stated:

> Okada discloses a video brightness control circuit having an average picture level of detector 20 which averages input picture information and provides a control signal to a variable correction circuit 10. The variable correction circuit operates on the input-output signal to vary the characteristic of the input-output signal as a function of the detected average picture level detector (see Fig. 2). Okada controls the relative brightness of the video signal such that the picture areas containing most of the picture information are corrected to give greater contrast. Although, Okada does not identically disclose all the element [sic] as recited in claims 1, 2, 8 and 9, Okada does provide a system which attempts to achieve the same results as the applicant. Both systems show an averaging circuit and a correction circuit which use the averaged information to produce an output which follows the slopes of the curves shown in Figure 2 of the present invention and Figure 2 of Okada.

128. I have reviewed the Okada patent and agree, generally, with the Examiner's comments that Okada shows an averaging circuit and a correction circuit that uses the averaged information.

129. In response to this rejection, the applicant did not disagree with the Examiner's analysis. Instead, the applicant amended claim 1 of the '381 patent to add the following elements (underlining shows new elements):

> (Amended) A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal <u>having a value within a determinate dynamic range of values and</u> corresponding to one of a plurality of succeeding pixels which collectively define an image, said system comprising:
>
> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged; and
>
> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel <u>wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.</u>

Claim 1 then issued in this form.

130. In response to the rejection of claim 8 over the Okada reference, the applicant amended claim 8 to include the following elements (underling shows added elements):

> (Amended) A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal <u>having a value within a determinate dynamic range of values and</u> corresponding to one of a plurality of succeeding pixels

> which collectively define an image, said method comprising the steps of:
>
> averaging the electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels;
>
> selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel; and
>
> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel <u>wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.</u>

Claim 8 then issued in this form, renumbered as claim 7.

131. Although Okada and the '381 patent produce similar nonlinear transformation results using an average-based gamma function, the '381 patent appears to have been allowed by the patent examiner because Okada does not explicitly disclose the language added to claims 1 and 7 of the '381 patent, i.e., a ratio of the value of an average signal to a value proportionate of the dynamic range of the signals to generate the nonlinear transformation illustrated in FIG. 2 of the Okada patent and FIG. 2 of the '381 patent.

132. However, that element, along with the other elements of claims 1 and 7, were well-known at the time the '381 patent was filed. The patents and references I discuss below were not considered by the Examiner during the examination of the application for the '381 patent.

IV. ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION USING THE CLAIM CONSTRUCTIONS PROPOSED BY POLAROID

133. In my review of claims 1-3 and 7-9 of the ‘381 patent, I have been told that if each element of a claim is found in a single prior art reference, the claim is invalid for what is called anticipation. I understand that for the claim to be anticipated, all of its requirements must have existed, expressly or inherently, in a single item of prior art. I have also been told that a claim is “obvious” if one of ordinary skill in the art would be motivated to modify an item of prior art, to combine two or more items of prior art to arrive at the claimed invention. When a patent simply arranges old elements with each performing the same function it had been known to perform and yields no more than one would expect from such an arrangement, the combination is likely to be obvious. In certain circumstances, the fact that a combination was obvious to try might show that it was obvious. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp.

134. I understand that HP and Polaroid have proposed different constructions of the disputed claims and that the Court has not yet ruled on the proper interpretation of these claims. I provide the following assessment of the novelty and obviousness of claims 1-3 and 7-9, on the assumption that the Court adopts Polaroid’s proposed construction of the claims. Using Polaroid’s proposed claim meanings, I believe that claim 7 of the ‘381 patent is anticipated by any one of Gonzalez[2], the Gonzalez algorithm[3], Richard[4], Lee[5], Sabri[6], Rangayyan[7], Chen[8],

[2] A chart identifying how Gonzalez teaches each and every element of claims 1 and 7 of the ‘381 patent and suggests the elements of claims 2-3 and 8-9 of the ‘381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix C.

[3] A chart identifying how the Gonzalez algorithm teaches each and every element of claim 7 of the ‘381 patent and suggests the elements of claims 2 and 3, as those claims are proposed to be understood by Polaroid, is attached as Appendix B.

Narendra[9] and Wang[10]. Further, claim 8 of the '381 patent is anticipated by Richard or Rangayyan. Claim 9 anticipated by Richards are obvious in view of any one of Gonzalez, Lee, Narendra, and Wang. Claim 1 is obvious in view of the Gonzalez algorithm in combination with any one of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen or Narendra. Claim 2 is obvious in view of the Gonzalez algorithm, combined with any one or Gonzalez, Richard, Rangayyan, Lee, or Narendra. Claim 3 is obvious in view of the Gonzalez algorithm, combined with any one of Gonzalez, Richard, Lee or Narendra.

135. I first assess claim 7, which is a method claim consisting of a preamble and three separate steps: (1) an averaging step, (2) a selecting step and (3) a transforming step. I will assess the preamble and each of these steps in turn.

<u>A method for continuously enhancing . . . .</u>

136. The preamble of claim 7 reads: "A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image."

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[4] A chart identifying how Richard teaches each and every element of claims 1-3 and 7-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix E.

[5] A chart identifying how Lee teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix F.

[6] A chart identifying how Sabri teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix G.

[7] A chart identifying how Rangayyan teaches each and every element of claims 7-8 of the '381 patent and suggests the elements of 1-3 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix H.

[8] A chart identifying how Chen teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix I.

[9] A chart identifying how Narendra teaches each and every element of claims 7 of the '381 patent and suggests the elements of 1-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix J.

[10] A chart identifying how Wang teaches each and every element of claim 7 of the '381 patent and suggests the elements of 1-3 and 8-9 of the '381 patent, as those claims are proposed to be understood by Polaroid, is attached as Appendix J.

137. I understand Polaroid's position to be that the preamble should not be considered an element of claim 7. However, I also understand that, in the event the preamble of claim 7 is found to be element of the claim, Polaroid believes that "*continuously enhancing*" should be construed to mean "successively transforming" and that *"electronic information signals*" should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values." See Joint Claim Construction Statement (Corrected).

138. Polaroid also believes that the term *"electronic image data received in a continuous stream of electronic information signals"* that appears in the preamble should be construed as "electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" and that the term "*each signal having a value within a determinate dynamic range of values"* should be construed as "each signal being associated with a value that lies within a range of possible values bounded by definite limits." (Id.)

139. As construed by Polaroid, the elements of the preamble are taught by each of Gonzalez, the Gonzalez algorithm Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

140. Gonzalez teaches methods for enhancing image data. (Gonzalez, Introduction and Chapter 4). An image is digitized into a numerical representation for input into a computer. (Gonzalez, p. 7, Section 1.3.2, line 1). The digitized images may comprise a number of pixels, each pixel having a value represented using eight bits. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). Gonzalez further explains that each pixel value represents one of a number of discrete gray levels (i.e., luminance) allowed for each pixel. (Gonzalez, p. 22, second paragraph). The number of luminance levels available for a pixel is dictated by the number of bits available to provide the numerical representation. (Id.; see Equation (2.3-3)). Because each pixel value in Gonzalez is a

number expressed as a certain number of bits, every luminance value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel *(x,y)*. Therefore, Gonzalez teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

141. The algorithm taught by Gonzalez enhances image data. (Gonzalez, Introduction and Appendix A). The program operates on digitized images that comprise a number of pixels. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). The Gonzalez algorithm each pixel value in an input image into one of a number of discrete gray levels available on the algorithm's intended device. (Gonzalez, p. 452-453). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every pixel value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel, I. Therefore, Gonzalez teaches successive transformation of pixel values, each pixel having a value that lies within a range of possible values that is bounded by definite limits.

142. Richard teaches methods for receiving and enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will, by definition, have a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and

all bits of the value equal to "1." Therefore, Richard teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

143. Lee teaches methods for enhancing digital image data. Each digital image is represented by a two-dimensional array of digital values - a table of rows and columns of pixel values that collectively define the image. (Lee, p. 165, Abstract). Each element of the two-dimensional array contains a luminance value for a pixel. (Lee, p. 165, Introduction, ll. 56-57). Lee teaches that an input image is transformed into a new image by performing a transformation of each individual pixel. (Lee, Eq. 5). Each value of a pixel is a number expressed as a certain number of bits; in this case, an 8-bit system which provides a dynamic range of 0 to 255. As every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Lee teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.

144. Sabri teaches methods for enhancing the quality of image data that makes up video images. Each video image is defined as a series of signals (pel or picture element values). (Sabri, col. 2, lines 18-27; col. 3, lines 45-49; col. 4, lines 44-49). The video signals are processed as they are received. (Sabri, Fig. 1). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, lines 18-21). For an 8-bit digital signal, the range of picture element values is from 0 to 255. (Sabri, col. 2, lines 44-46). As with Lee, by definition, the signals of Sabri lie within a range of possible values bounded by definite limits – the dynamic range of an 8-bit system. Therefore, Sabri teaches successive transformation of picture element

values defining an original video image, each picture element value lying within a range of possible values that is bounded by definite limits.

145. Rangayyan teaches methods for performing adaptive local contrast enhancement on a series of pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Because each pixel value in Rangayyan is a number expressed as six bits, every pixel value will, by definition, have a value within a range of possible values and the range of possible values is bounded by definite limits; i.e., all six bits of the value equal to "0" and all six bits of the value equal to "1." Each pixel is processed sequentially. (Rangayyan, p. 561, col. 2). Therefore, Rangayyan teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

146. Chen teaches methods for enhancing electronic image data and, in particular, applying image enhancement and image improvement techniques to magnetic resonance images stored as a matrix or array of pixel values. (Chen, col. 1, ll. 5-10, col. 1 ll. 64-66 and col. 3, ll. 20-21). These pixel values represent a grayscale intensity (i.e. luminance) of a human-readable image. (Chen, Abstract, lines 3-6). The pixel values are digital values. (Chen, col. 5, ll. 14-17). The pixel values, therefore, are values within a range of possible values bounded by definite limits; i.e., the dynamic range afforded by the number of bits used to represent the pixel values. Each pixel is processed sequentially. (Chen, col. 8, ll. 6-15). Therefore, Chen teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

147. Narendra teaches methods for implementation of an adaptive contrast enhancement scheme for image data using local area statistics (Narendra, p. 655, Abstract; p.

656, third paragraph). The image is represented by pixel values in an array. (Narendra, p. 657, col. 2, last paragraph). The pixel values represent intensity information (i.e. luminance) from a scene detected by imaging sensors. (Narendra, p. 655, Abstract, lines 3-6; p. 655, col. 2, Introduction, first paragraph, lines 1-2 and second paragraph, lines 2-3; p, 656, col. 1, fourth paragraph, lines 4-6). The luminance at each point is transformed based on local area statistics. (Narendra, p. 656, col. 2, Eq. 1). The luminance values are digital values and, therefore, are values within a range of possible values having defined limits. Therefore, Narendra teaches successive transformation of luminance values that collectively define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

148. Wang teaches digital enhancement techniques to improve picture quality. (Wang, p. 363, Introduction, line 1). Wang defines an image as a collection of pixels, each pixel at a coordinate *x* and *y* in a rectangular representation of an image. (Wang, p. 365, Section 2. Notation; Figures (4-1), (4-2) and (4-3)). Each of the pixels has a value representing a gray level that lies within a minimum and a maximum gray level of the image. (Wang, p. 365, Section 2, Notation). Thus, the value of a pixel lies within a range of possible values defined by the bounds of a minimum value and a maximum value. Each pixel is processed sequentially. (Wang, Eq. 6-4). Therefore, Wang teaches successive transformation of luminance image data defining an original image, each luminance signal having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

<u>…averaging the electronic information signals….</u>

149. Following the preamble, claim 7 continues: "*averaging* the electronic information signals corresponding to selected pluralities of pixels and providing an *average electronic information signal* for each said plurality of pixels."

150. I understand that Polaroid contends that "*averaging*" should be construed to mean "calculating an intermediate value" and that "*average electronic information signal*" should be construed to mean "the signal providing pixel information, such as a color, luminance, or chrominance value of the calculated intermediate value." *See* Joint Claim Construction Statement (Corrected).

151. As construed by Polaroid, this step reads as calculating an intermediate value for a selected group of pixels and providing the intermediate calculated value for each of the groups of pixels. Such methods are taught by each of Gonzalez, the Gonzalez algorithm Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang

152. Gonzalez teaches computing an average value for a selected group of pixels and providing the average value for each group of pixels referred to in Gonzalez as *m(x,y)*. (Gonzalez, pp. 158-163). A neighborhood averaging technique calculates an average luminance value by averaging the luminance values of a selected group of pixels referred to as a neighborhood. (Gonzalez, p. 161, Section 4.3.1, first paragraph). The neighborhood of pixels may be a square, such as a 3 by 3 matrix surrounding a pixel that includes the pixel itself. (Id.) The average is calculated by adding the luminance values of the pixels in the neighborhood and dividing by the number of pixels in the neighborhood. (Gonzalez, p. 161, Equation (4.3-1)). This calculation produces an intermediate calculated value providing pixel information. Thus, Gonzalez teaches calculating an intermediate value for each selected group of pixels that provides pixel information.

153. The Gonzalez algorithm teaches computing an intermediate calculated value for a selected group of pixels and providing the intermediate calculated value for each of the group of

pixels. The Gonzalez algorithm computes a calculated intermediate value for a group of pixels using the following function, *SS:*

SS=(*-1/GN*) * ALOG (*FH/T*)

GN contains a value of 32, representing the maximum value of the dynamic range of the intended output device (in this case, a line-printer). *FH* represents the maximum gray level value of the group of pixels representing the input image. (Gonzalez, p. 453, line 4). *T* represents the minimum gray level of the group of pixels representing the input image (Gonzalez, p. 453, line 3). The Gonzalez algorithm therefore, teaches computing an intermediate calculated value for a selected group of pixels and providing the intermediate calculated value . In this case, a logarithmic function, ALOG, of the ratio of *FH to T*.

154. Richard teaches "a means for computing a local mean value M_v of luminance of a point being processed." (Richard, Col. 1, ll. 62-63). A horizontal filtering device and a vertical filtering device as shown in Figure 1 of Richard are connected in series to produce the local mean value M_v. (Richard, col. 4, ll. 46-53). The filtering devices receive a sequence of numerical luminance values of points in a field representing an image. Each field of the image consists of multiple lines, for example, 256 lines, and each line has multiple points or luminance values, for example, 512 points. (Richard, col. 3, ll. 32-43). The filtering devices of Richard compute the local mean value for a line from the luminance values of points on the line. (Id.). The local mean value is provided as the mean for the selected group of luminance values. (Richard, see output M_v from element 6 in the single Figure). The local mean value produced by the filtering devices is an expression of the mean value that would be obtained by computing an arithmetic mean. (Id.). Richard, therefore, teaches calculating an intermediate value (in this case, the local mean) for each selected groups of pixels that provides pixel information.

155. Lee teaches a method in which a mean value for each input pixel is derived from the local mean of all pixels within a fixed range surrounding the input pixel. (Lee, p. 165, Abstract, ll. 8-10; p. 165, col. 2, Introduction, ll. 17-22). A two-dimensional array stores a luminance value for each pixel of an image. (Lee, p. 165, col. 2, last paragraph). A local mean $m_{i,j}$ is calculated over a window having a predetermined number of rows and columns. (Lee, p. 166, Equation 1). The window is a rectangular region surrounding the input pixel. Equation 1 sums all the luminance values in the surrounding region and divides by the total number of values in this region (Id.). Lee, therefore, teaches calculating an intermediate value for each selected group of pixels that provides pixel information.

156. Sabri teaches computing for a pixel an average of luminance values of neighboring pixels. (Sabri, Abstract). The summing means of Figure 1 serves to compute, for a group of pixels, a weighted average according to the identified formula. (Sabri, col. 3, 38-47). This weighted average is an intermediate calculated value that provides pixel information. Therefore, Sabri teaches calculating an intermediate value for a selected group of pixels that provides pixel information.

157. Rangayyan teaches calculating average pixel value of a group of pixels in a region surrounding the pixel being processed. (Rangayyan, p. 561, col. 2, Section C, first paragraph). Therefore, Rangayyan teaches calculating an intermediate value (in this case, an average) that provides pixel information.

158. Chen teaches computing the mean of pixel values of a selected group of pixels referred to as a neighborhood. (Chen, Abstract, 10-13). The image enhancing circuit (Chen, Fig. 1, element C) of Chen includes a pixel value averaging means (Chen Fig. 1, element 40) to generate a mean pixel value. (Chen, col. 5, ll. 25-27). By way of example in Figure 2, a mean

value is computed to represent the average of 25 pixel values in a 5 by 5 neighborhood centered around a pixel being processed. (Chen, col. 5, ll. 39-42). This average is a calculated intermediate value and is provided for the group of pixels of the surround region. Chen, therefore, teaches a calculated intermediate value (in this case, an average) for each group of pixels that provides pixel information.

159. Narendra teaches calculating a local mean for a pixel, referred to as M_{ij}, for a local area surrounding the pixel. (p. 656, col. 2, ll. 3-6). Narendra, therefore, teaches an intermediate calculated value (in this case, a mean) for each group of pixels that provides pixel information.

160. Wang teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. (see Wang, p.367, first paragraph). Wang takes an average (i.e., an intermediate calculated value) over a rectangular neighborhood surrounding the pixel being processed. (Id.; Equation (4-1) and (4-2)). Therefore, Wang also teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels

...selecting one of a plurality of different transfer functions….

161. The next step of claim 7 reads: "selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel."

162. I understand that Polaroid construes this step to mean: "selecting one of a plurality of different transfer functions for the signal providing pixel information, such as a color, luminance, or chrominance value for each of the plurality of succeeding pixels in a manner

whereby each transfer function is selected as a function of the signal providing pixel information, such as a color, luminance, or chrominance value for one pixel and the calculated intermediate value for the select plurality of pixels containing said one pixel". *See* Joint Claim Construction Statement (Corrected).

163. As construed by Polaroid, this step means that a transfer function is selected for each pixel being processed that is a function of (1) the input pixel value and (2) the calculated intermediate value for the group of pixels containing the input pixel. The calculated intermediate value is produced from the "averaging" step of this method discussed above. The transfer function is any function that transforms the pixel being processed. Thus, according to Polaroid, any function that transforms a pixel being processed using (1) the value of the pixel and (2) the calculated intermediate value satisfies this claim element. Such functions are taught by each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

164. Gonzalez teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Gonzalez, p.159, last paragraph to p. 160, first and second paragraph). The value of the pixel being processed, referred to in Gonzalez as *f(x,y),* is transformed into a new pixel value, referred to as *g(x,y)* using the transfer function illustrated by Equation (4-2-14). (Gonzalez, p. 160). This transfer function uses the value of the pixel *f(x,y)* in its computations. This transfer function also uses the calculated intermediate value - the mean of the pixel values for a group of pixels including the pixel being processed, referred to as *m(x,y)* in its computation. The result of this computation using the value of the pixel *f(x,y)* and the average value *m(x,y)* results in a transformed value for the pixel *g(x,y).* Therefore, Gonzalez teaches selecting a transfer function for the pixel being processed using the value of

the pixel and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

165. The Gonzalez algorithm teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which in this case, ALOG (*FH/T*). The Gonzalez algorithm provides the following transfer function:

$$FLEV = FH * \mathrm{EXP}(SS*(GN-I)) + 0.5$$

(Gonzalez, p. 454, see computation of variable SS). *I* represents the input pixel value. GN represents the maximum value of the dynamic range of the intended output device. *SS* is a function computed as follows:

$$SS = (-1/GN) * \mathrm{ALOG}\ (FH/T)$$

(Gonzalez, p. 454, see computation of variable SS). Gonzalez, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel *I*, and the calculated intermediate value, ALOG (*FH/T*).

166. Richard teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value. (Richard, Fig. 1). As shown in Figure 1, the value Y_{ij}/M_g is generated from the multiplier component (Richard, Fig. 1, 10) and is dependent on the pixel value Y_{ij}. Richard teaches that the calculated local mean, M_v, is then multiplied by that result. Richard teaches, therefore, selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which is the local mean value, M_v.

167. Lee teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Lee, p. 166, Section II, ll. 3-5, Eq. 4). This

algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Lee, p. 166, ll. 1-4 after Eq. (4)). Lee teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

168. Sabri teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value, which for Sabri is an average of the pixel values preceding the pixel being processed. (Sabri, col. 2, ll. 4-14). A contrast enhancement factor γ_{ij} is derived from the pixel value, C_{ij}. (Sabri, col. 2, ll. 29-39). The contrast enhancement factor is then added to a calculation that includes the intermediate calculated value, i.e., the average ϕ of the pixels preceding the pixel being processed. Sabri, therefore, teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value, which for Sabri is the average value of the pixels preceding the pixels being processed.

169. Rangayyan teaches selecting a transfer function based on the input pixel value and a calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, a. Rangayyan states that a contrast enhancement factor, C, is calculated using the value of the pixel being processed, p, and the average, a, of a group of pixels in the neighborhood around p. The contrast factor is used, as part of a final transformation equation, to transform each pixel value. Therefore, Rangayyan teaches selecting a transfer function for the pixel being processed using the value of the pixel and calculated intermediate value which, for Rangayyan, is the average value of a group of pixels surrounding the pixel being processed, a.

170. Chen teaches selecting a transfer function for each pixel based on the pixel value and the calculated intermediate value which, for Chen, is the mean of pixel values of a selected group of pixels referred to as a neighborhood. (Abstract, Chen). A transfer function provides an improved pixel value by subtracting the mean neighborhood value from the value of the pixel. (Chen, col. 8, l-11; Eq. 11). This difference between the pixel value and the intermediate calculated value is multiplied by a transfer function. (Id.). Therefore, Chen teaches selecting a transfer function for the pixel being processed using the value of the pixel and the calculated intermediate value which, for Chen, is the mean of pixel values of a selected group of pixels referred to as a neighborhood.

171. Narendra teaches selecting a transfer function for the pixel being processed based on the pixel value and the calculated intermediate function which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed. (Narendra, p. 656. Section II, paragraph 5). In the transformation formula of Equation 1, this intermediate calculated value is subtracted from the pixel value. (Narendra, p. 656, col. 2, Eq. 1). This difference is multiplied by a variable gain function. Therefore, Narendra teaches selecting a transfer function for the pixel being processed using the value of the pixel and a calculated intermediate value which, for Narendra, is a local area mean value computed from a local area surrounding the pixel being processed.

172. Wang teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Wang, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Wang, p. 166, ll. 1-4

after Eq. (4)). Wang teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

<u>…transforming the electronic information signal…</u>

173. The last step of the method of claim 7 recites:

> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

174. Polaroid provides the following definition for the transformation step:

> transforming the signal providing pixel information … corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of that calculated intermediate value over a value that lies within a range bounded by definite limits such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value. *See* Joint Claim Construction Statement (Corrected).

175. As construed by Polaroid, this step states that the pixel being processed is transformed using the selected transfer function, provided that the transfer function is further selected as a function of a ratio of a calculated intermediate value over any value within a range of possible values bounded by definite limits. That is, the function that transforms the input signal is further selected a function of the following ratio:

calculated intermediate value / a value within a range of values.

176. As construed by Polaroid, functions of this type are taught by each of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang.

177. Gonzalez teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the values for a group of pixels that includes the subject pixel) over a value that lies within a range bounded by definite

limits. The value of the pixel being processed, referred to as *f(x,y),* is transformed into a new pixel value, referred to as *g(x,y)* using the following transfer function illustrated by Equation (4-2-14):

$$g(x,y) = A(x,y) \times \left[f(x,y) - m(x,y) \right] + m(x,y)\,.$$

(Gonzalez, p. 160).

The transformation function *g(x,y)*, therefore, transforms an original pixel value into a new pixel value using a gain referred to as *A(x,y)* that is defined as follows:

$$A(x,y) = \frac{k \times M}{\sigma(x,y)} \text{ for } 0 < k < 1.$$

(Id.).

When the gain *A(x,y)* is replaced with its definition in the equation, the transfer function becomes:

$$g(x,y) = \frac{k \times M}{\sigma(x,y)} \times \left[f(x,y) - m(x,y) \right] + m(x,y)$$

which, in turn, may also be represented as:

$$g(x,y) = \frac{k \times M \times f(x,y)}{\sigma(x,y)} - \frac{k \times M \times m(x,y)}{\sigma(x,y)} + m(x,y)\,.$$

The equation above shows that *f(x,y)* is transformed into *g(x,y)* using a function selected as a ratio of the mean of pixel values for a group of pixels that includes the subject pixels over the standard deviation, *σ(x,y)* of the pixels in the group. The standard deviation is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Gonzalez, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean of the pixel

values for a group of pixels that includes the subject pixel) over a value within a range of values (in this case, the standard deviation of the pixels in the group).

178. The Gonzalez algorithm teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values. The Gonzalez algorithm transforms an input pixel, *I*, into an output pixel value *FLEV* as follows:

FLEV = *FH** EXP(*SS**(*GN*-*I*)) + 0.5

(Gonzalez, p. 454, see computation of variable SS). In the above computer instructions, the transfer function is selected as a ratio of the calculation intermediate value, ALOG (*FH/T*) over a value in the range of values because the function SS is computed as follows:

SS = (-1/*GN*) * ALOG (*FH/T*)

(Gonzalez, p. 454, see computation of variable SS). *GN* represents the maximum value of the intended output device. *GN*, therefore, is a value in a range bounded by definite limits (in this case 0 to 31). Therefore, Gonzalez teaches transforming an input signal, *I*, where the transfer function is further selected as a ratio of the calculated intermediate value, ALOG (*FH/T*) over a value in the range of values (in this case, *GN*).

179. Richard teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values (in this case, the local mean value for a group of pixels M_v) over a value that lies within a range bounded by definite limits. Richard transforms an input signal using the function depicted as element 5 in Figure 1:

$$Y'_{ij} = Y_{ij} \times \frac{M_v}{M_g} \times k \, .$$

(Richard, col. 2, ll. 21-25; Fig. 1).

In Figure 1, Richard illustrates the use of the pixel value (referred to as Y_{ij}), a local mean value of a group of pixels, M_v, and a ratio of the local mean value to the global mean value (M_v/M_g) to produce the transformed value of Y_{ij} times the ratio of M_v/M_g and a constant K. (Richard, Figure 1, elements 10-14). The global mean M_v is an intermediate value providing pixel information. (Richard, col. 1, ll. 58-68). The denominator of this ratio, M_g, has a value within a range of possible values. The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Richard, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local mean value M_v) over a value within a range of values (in this case, the global mean value, M_g).

180. Lee teaches transforming an input signal where the transfer function is further selected as a ratio a calculated intermediate value (in this case, the local mean of the pixel values for a group of pixels including the input pixel) over a value that lies within a range bounded by definite limits. The following algorithm of Lee transforms the input pixel by subtracting the local mean from the value of the pixel, multiplying this difference by a gain k and adding the result to the local mean to provide the transformed pixel value $x'_{i,j}$:

$$x'_{i,j} = m_{i,j} + k(x_{i,j} - m_{i,j}) \quad \text{where } k = \sqrt{\frac{v_{i,j}}{v_{orig}}}$$

(Lee, p. 166, Equation (4)).

In the above equation, $x_{i,j}$ represents the value of the input pixel and $m_{i,j}$ the local mean for the pixel at (i,j). The calculation $x_{i,j} - m_{i,j}$ subtracts the local mean from the value of the pixel being processed. The local mean is an intermediate calculated value of a selected group of pixel values including the input pixel. (Lee, p.165, col. 2 last paragraph and p. 166, Equations (1) and (2)). The result of the subtraction operation is multiplied by a gain referred to as k. The gain k is

defined as a ratio of a local standard deviation (i.e., square root of local variance of pixels in a group of pixels) to an original standard deviation (i.e., square root of original variance of pixels in a group of pixels). (Id). When the gain *k* is replaced with its definition in the above equation, the transformation function becomes:

$$x'_{i,j} = m_{i,j} + \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot \mathrm{x}'_{\mathrm{i,j}} - \sqrt{\frac{v_{i,j}}{v_{orig}}} \cdot m_{i,j}$$

The standard deviation (i.e., the square root of a variance) is the average deviation of a pixel value from the average pixel value of a group of pixels. The standard deviation, by definition, is a value that falls within the range of values defined by the dynamic range. Lee, therefore, teaches transforming a pixel where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the local means value, $m_{i,j}$) over a value within a range of values (in this case, the original standard deviation).

181. Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case, the mean of the pixel values for a group of pixels preceding the pixel being processed) over a value that lies within a range bounded by definite limits. Sabri transforms an input signal using the transformation function, B_{ij}, γ

$$Bij = \gamma ij + \left(\frac{1-2\gamma ij}{R}\right)\phi ij$$

(Sabri, col. 2, ll. 40-46).

In the equation above ϕ_{ij}, is a weighted average of picture element values, which is the calculated intermediate value providing pixel information. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). *R* is the maximum range of input picture element values. (Sabri, col. 2, ll. 40-46).

Expanding this expression gives:

$$Bij = \gamma ij + \frac{\phi ij - 2 \times \phi ij \times \gamma ij}{R} \quad \text{or} \quad Bij = \gamma ij + \frac{\phi ij}{R} - \frac{2 \times \phi ij \times \gamma ij}{R}$$

Therefore, Sabri teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (the weighted average, ϕ_{ij}) over a value within a range of values (in this case, the maximum value of the dynamic range, *R*).

182. Rangayyan teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value over a value that lies within a range bounded by definite limits. (Rangayyan, p. 561, Section C, Contrast Enhancement). Rangayyan computes a contrast measure *C* using the input pixel value, *p*, and the average value, *a*, of the values of the pixels surrounding *p*:

$$C = \frac{|p - a|}{(p + a)}$$

(Rangayyan, p.561, col. 2).

A new pixel value is calculated from the square root of *C*, referred to as *C'*, and the average *a* as follows:

$$p' = a \times \frac{(1 + C')}{(1 - C')} \text{ if } p \geq a \text{, and also } \quad p' = a \times \frac{(1 - C')}{(1 + C')} \text{ if } p < a$$

Expanding the transfer mathematically gives:

$$p' = a \times \frac{1 + \sqrt{\frac{|p - a|}{(p + a)}}}{1 - \sqrt{\frac{|p - a|}{(p + a)}}} \text{ for } p \geq a \text{, and } \quad p' = a \times \frac{1 - \sqrt{\frac{|p - a|}{(p + a)}}}{1 + \sqrt{\frac{|p - a|}{(p + a)}}} \text{ for } p < a$$

The transfer function *p'* is then used in a transformation function, *p"*, as follows:

$$p" = 255 \times \frac{(p' - \min)}{\max - \min} \text{ for positive mode}$$

$$p" = 255 \times \frac{(\max - p')}{(\max - \min)} \text{ for negative mode}$$

(Id.).

Max refers to the maximum pixel value and min refers to the minimum pixel value. Replacing *p'* in this equation with its definition above gives:

$$p" = 255 \times \frac{\left(a \times \dfrac{1 + \sqrt{|p-a| \big/ (p+a)}}{1 - \sqrt{|p-a| \big/ (p+a)}} \right) - \min}{\max - \min} \text{ for positive mode and}$$

$$p" = 255 \times \frac{\max - \left(a \times \dfrac{1 - \sqrt{|p-a| \big/ (p+a)}}{1 + \sqrt{|p-a| \big/ (p+a)}} \right)}{\max - \min} \text{ for negative mode}$$

The contrast measure *C*, which is the ratio of the absolute value of the difference $|p - a|$ over $(p + a)$ is the calculated intermediate value providing pixel information. The value "*max – min*" represents a value within a range of possible values. Therefore, Rangayyan teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the contrast measure, C,

which is itself a function of the mean of the pixel values of a group of neighboring pixels) over a value within a range of values (in this case, *max-min*).

183. Chen teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a selected group of pixels in the neighborhood of the input pixel) over a value that lies within a range bounded by definite limits. Chen uses the following function to replace each input pixel value *I(i,j)* with an improved pixel value *I'(i,j)*:

$$I'(i,j) = G(i,j) \times \left\{ I(i,j) - \overline{I(i,j)} \right\} + \overline{I(i,j)}$$

(Id.).

G(i,j) refers to a gain function and $\overline{I(i,j)}$ is a mean of pixel values of neighboring pixels. Chen teaches that the transfer function *G(i,j)* may be expressed as:

$$G(i,j) = \frac{\log(n) - \log(m)}{\log K(n) - \log K(m)}$$ in which *K(n)* and *K(m)* are average differences between the pixel at (*i,j*) and the values of the pixels lying within two circular areas having radius of *n* and *m*, respectively.

Replacing the value of *G(i,j)* in the transform function $\overline{I(i,j)}$ with its expression, the equation becomes:

$$I'(i,j) = \frac{\log(n) - \log(m)}{\log(K(n)) - \log(K(m))} \times \left\{ I(i,j) - \overline{I(i,j)} \right\} + \overline{I(i,j)}$$

This same equation may be represented as:

$$I'(i,j) = \frac{\{\log(n) - \log(m\} \times I(i,j)\}}{\log(K(n)) - \log(K(m))} - \frac{\{\log(n) - \log(m\} \times \overline{I(i,j)}\}}{\log(K(n)) - \log(K(m))} + \overline{I(i,j)}$$

Chen, therefore, teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this

case, the mean value, $\overline{I(i,j)}$, of pixels in the neighborhood of the input pixel) over a value within a range of values (in this case, the difference of the logarithmic value of the first average difference and the logarithmic value of the second average difference (i.e. $log(K(n))\text{-}log(K(m))$).

184. Narendra teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate value (in this case the mean of the pixel values for a local group of pixels, M_{ij}, over a value that lies within a range bounded by definite limits. The following transformation function uses the pixel value I_{ij} of the pixel being processed and a mean value M_{ij} to provide the improved pixel value $\hat{I}_{ij}$:

$$\hat{I}_{ij} = G_{ij} (I_{ij} - M_{ij}) + M_{ij}$$

(see Narendra, p. 656, Equation (1)).

G_{ij} is a gain factor. The local mean value M_{ij} is an intermediate calculated value computed on a group of pixels surrounding the pixel being processed. (Narendra, p. 65, first paragraph). The transformation function takes the difference between the pixel value I_{ij} and the local mean M_{ij} and multiplies the result by a gain referred to as G_{ij}.

$$G_{ij} = \alpha \frac{M}{\sigma_{ij}}, \quad 0 < \alpha < 1$$

(Id.)

When the gain G_{ij} is replaced with its definition in the above equation, the transformation function becomes:

$$\hat{I}_{ij} = (\alpha \frac{M}{\sigma_{ij}} \cdot I_{ij}) - (\alpha \frac{M}{\sigma_{ij}} \cdot M_{ij}) + M_{ij}$$

which, in turn, becomes:

$$\hat{I}_{ij} = \left(\frac{\alpha \cdot M \cdot I_{ij}}{\sigma_{ij}} \right) - \left(\frac{\alpha \cdot M \cdot M_{ij}}{\sigma_{ij}} \right) + M_{ij}$$

The σ_{ij} is the standard deviation of local pixel values, α is a gain factor and M is the global mean. Therefore, Narendra teaches using a function that transforms an input signal where the transfer function is further selected as a function of a ratio of the calculated intermediate value (in this case, the local mean value, M_{ij}) over a value within a range of values (in this case, a standard deviation value).

185. Wang teaches selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value, which is the local mean value for the group of pixels surrounding the pixel being processed. (Wang, p. 166, Section II, ll. 3-5, Eq. 4). This algorithm provides an enhanced value for each pixel by taking the difference between the value of the pixel being processed and the computed local mean value. (Wang, p. 166, ll. 1-4 after Eq. (4)). Wang teaches, therefore, selecting an algorithm for a transfer function based on the pixel being processed and the calculated intermediate value which is the mean of the pixel values for a group of pixels including the pixel being processed.

186. Because each and every element of claim 7 can be found in any one of Gonzalez, the Gonzalez algorithm, Richard, Lee, Sabri, Rangayyan, Chen, Narendra and Wang, I am of the opinion that claim 7 is anticipated, as that concept has been explained to me, by each one of those references.

187. Claim 8 reads:

> The method of claim 7 wherein the transfer function is selected in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

188. Claim 8, therefore, requires a method having all the elements of claim 7 and the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light condition or when a calculated intermediate value indicates a high light condition. Such functions are taught by Richard or Rangayyan and are suggested by any one of Gonzalez, Lee, Narendra or Wang.

189. Richard teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors when the local mean, M_v, represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of a pixel being processed responsive to the ratio M_v/M_g. (Richard, col. 5, line 62 to col. 6, line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black when the local mean value associated with the pixel is less than the global mean value for the image as a whole and increases the luminance value of the pixel being processed closer to white when the local mean value associated with the pixel is greater than the global mean value for the image as a whole. (Id.) "In the case of areas which are darker than the general mean value, these areas have an even darker appearance after processing." (Richard, col. 6, lines 10-14). Richard provides higher contrast for very dark and very light pixels because the ratio of *Mv/Mg* will be very close to 0 (for very dark pixels) and will be large for very light pixels. This means that the value of a very dark pixel will be multiplied by a fraction, resulting in a darker appearance for that pixel and a very light pixel will be multiplied by a number greater than 1, which will result in a lighter appearance for that pixel. The darkest areas will be made darker relative to less dark areas and the lightest areas will be made lighter relative to less light areas. Richard, therefore, teaches selecting the transfer function to provide higher contrast to a pixel when a calculated intermediate value represents a very dark or very light condition.

190. Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average $|p\text{-}a|$. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C,* will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

191. Because Richard and Rangayyan both disclose each and every element of claim 8 of the '381 patent, I believe that Richard or Rangayyan anticipates claim 8, as it is proposed to be construed by Polaroid.

192. Gonzalez teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors pixels when a calculated intermediate value represents a very dark or very light condition (Gonzalez, p, 141). Gonzalez teaches multiplying the difference between the value of an input pixel and the mean value of the neighboring pixels by a gain factor, *A(x,y).* (Gonzalez, Eq. 4.2-14). The gain factor is calculated by multiplying a constant, *K,* by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. (Gonzalez, Eq.

4.2-15). This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because k is a constant and the global mean, M, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor taught by Gonzalez to further increase the contrast of luminance levels in very dark or very light areas of the image. It would be obvious to identify very dark and very light areas of the image using with the mean value of the neighboring pixels. In this way the gain would increase in areas of low light or high light. Therefore, I believe that claim 8 is obvious in view of Gonzalez.

193. Lee teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Lee teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Lee, p. 166, col. 1, last paragraph). "The linear function … yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee with a function that increased the "stretch" in areas of very low light or very high light, because that would allow Lee to further increase contrast at both ends of the gray scale. Therefore, I believe claim 8 is an obvious extension of Lee.

194. Narendra teaches that the local area mean is subtracted from the value of a pixel being processed and a gain is applied to the difference. (Narendra, p. 656, col. 2, second paragraph). The gain taught by Narendra is calculated by multiplying a constant, α., by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because α is a constant and the global mean, M, is a constant value for an image. I believe that it would have

been obvious to try modifying the gain factor taught by Narendra to further increase the content of luminance levels in very dark or very light areas of the image. It would be obvious to identify very dark and very light areas of image using the mean value of the neighboring pixels. In this matter the gain would increase in areas of low light or high light. Therefore, I believe claim 8 is obvious in view of Narendra.

195. Wang teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Wang teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Wang, p. 166, col. 1, last paragraph). "The linear function … yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee with a function that increases the "stretch" in areas of very low light or very high light, because that would allow Wang to further increase contrast at both ends of the gray scale.

196. Claim 9 reads:

> The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.

197. Claim 9, therefore, recites a method having all the elements of claim 8 and claim 7, and the element that the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed in areas of the image where higher contrast has been provided by the transfer function. Such functions are taught by Richard and are suggested by any one of Gonzalez, Lee, Narendra or Wang.

198. Richard teaches a system in which a constant value, *K*, can be adjusted by an operator "to control the contrast." (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value, *Yij*, multiplied by *(Mv/Mg)*, and further multiplied by a constant *K* (Richard, Fig. 1). An increase in *K* will increase the constant between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the lightest areas of an image, and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

199. Because Richard teaches each and every element of claim 9 of the '381 patent, I am of the opinion that Richard anticipates claim 9, as that claim is proposed to be construed by Polaroid.

200. Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function *g(x,y)* applies a local gain factor *A(x,y)* to the difference between the pixel value being processed *f(x,y)* and the local mean *m(x,y)* of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor *A(x,y)* amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these contrast areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

201. Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, k. (Lee, p.166, col. 1, Eq. 4). A higher value of k results in a higher output pixel value than a lower values of k will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Lee.

202. Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by multiplying a constant value, referred to as α, by the global mean (M) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain factor results in a higher output pixel value than a lower gain factor will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Narendra, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Narendra.

203. Wang teaches using the contrast gain factor of a constant k as also taught by Lee. (Wang, p. 376, Equation (6-4)). As in Lee, Wang teaches that a constant k is multiplied by the difference between the value of the pixel itself g(x,y) and the mean value of the pixels surrounding this pixel, $\breve{g}(x,y)$. A higher value of k results in a higher output pixel value than will

result using lower values of *k* will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Wang, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Wang.

<u>Claim 1</u>

204. Independent claim 1 consists of a preamble and two Gonzalez claim elements: a means for averaging; and a means for selecting and transforming.

205. The preamble of claim 1 reads as follows:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image

206. I understand Polaroid's position to be that the preamble should not be considered a element of claim 1. However, I also understand that, in the event the preamble of claim 1 is found to be element of the claim, Polaroid believes that "*continuously enhancing*" should be construed to mean "successively transforming" and that *"electronic information signals*" should be construed to mean "signals providing pixel information, such as color, luminance, or chrominance values." See Joint Claim Construction Statement (Corrected).

207. Polaroid also asserts that the term *"electronic image data received in a continuous stream* of *electronic information signals"* that appears in the preamble should be construed as "electronic data received in a successive series of signals providing pixel information, such as color, luminance, or chrominance values" and that the term "*each signal having a value within a determinate dynamic range of values"* should be construed as "each

signal being associated with a value that lies within a range of possible values bounded by definite limits." (Id.)

208. As construed by Polaroid, the elements of the preamble are taught by each of the Gonzalez algorithm, Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.

209. The algorithm taught by Gonzalez enhances image data. (Gonzalez, Introduction and Appendix A). The program operates on digitized images that comprise a number of pixels. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). The Gonzalez algorithm each pixel value in an input image into one of a number of discrete gray levels available on the algorithm's intended device. (Gonzalez, p. 452-453). Because each pixel value in Gonzalez is a number expressed as a certain number of bits, every pixel value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel, I. Therefore, Gonzalez teaches successive transformation of pixel values, each pixel having a value that lies within a range of possible values that is bounded by definite limits.

210. Gonzalez describes a system for enhancing image data. (Gonzalez, Introduction and Chapter 4). An image is digitized into a numerical representation for input into a computer. (Gonzalez, p. 7, Section 1.3.2, line 1). The digitized images may comprise a number of pixels, each pixel having a value represented using eight bits. (Gonzalez, p. 10, Section 1.3.4, ll. 1-2). Gonzalez further explains that each pixel value represents one of a number of discrete gray levels (i.e., luminance) allowed for each pixel. (Gonzalez, p. 22, second paragraph). The number of luminance levels available for a pixel is dictated by the number of bits available to provide the numerical representation. (Id.; see Equation (2.3-3)). Because each pixel value in Gonzalez is a

number expressed as a certain number of bits, every luminance value will have, by definition, a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Gonzalez teaches that an input image is transformed into a new image by performing a transformation of each individual pixel *(x,y)*. Therefore, Gonzalez teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

211. Richard describes a system for receiving and enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will, by definition, have a value within a range of possible values bounded by definite limits; those limits are all bits of the value equal to "0" and all bits of the value equal to "1." Therefore, Richard teaches successive transformation of luminance values of pixels that, together, define an original image, each pixel having an associated luminance value that lies within a range of possible values that is bounded by definite limits.

212. Lee describes a system for enhancing digital image data. Each digital image is represented by a two-dimensional array of digital values - a table of rows and columns of pixel values that collectively define the image. (Lee, p. 165, Abstract). Each element of the two-dimensional array contains a luminance value for a pixel. (Lee, p. 165, Introduction, ll. 56-57). Lee teaches that an input image is transformed into a new image by performing a transformation of each individual pixel. (Lee, Eq. 5). Each value of a pixel is a number expressed as a certain number of bits; in this case, an 8-bit system which provides a dynamic range of 0 to 255. As

every pixel value is within the dynamic range, then, by definition, each value is within a range of possible values bounded by definite limits; those limits are 0 (0000 0000) and 255 (1111 1111). Therefore, Lee teaches successive transformation of signals providing pixel information, each signal having a value that lies within a range of possible values that is bounded by definite limits.

213. Sabri describes a system for enhancing the quality of image data that makes up video images. Each video image is defined as a series of signals (pel or picture element values). (Sabri, col. 2, lines 18-27; col. 3, lines 45-49; col. 4, lines 44-49). The video signals are processed as they are received. (Sabri, Fig. 1). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, lines 18-21). For an 8-bit digital signal, the range of picture element values is from 0 to 255. (Sabri, col. 2, lines 44-46). As with Lee, by definition, the signals of Sabri lie within a range of possible values bounded by definite limits – the dynamic range of an 8-bit system. Therefore, Sabri teaches successive transformation of picture element values defining an original video image, each picture element value lying within a range of possible values that is bounded by definite limits.

214. Rangayyan describes a system for performing adaptive local contrast enhancement on a series of pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Because each pixel value in Rangayyan is a number expressed as six bits, every pixel value will, by definition, have a value within a range of possible values and the range of possible values is bounded by definite limits; i.e., all six bits of the value equal to “0” and all six bits of the value equal to “1.” Each pixel is processed sequentially. (Rangayyan, p. 561, col. 2). Therefore, Rangayyan teaches successive transformation of luminance values that, together, define an

original image, each luminance value lying within a range of possible values that is bounded by definite limits.

215. Chen describes a system for enhancing electronic image data and, in particular, applying image enhancement and image improvement techniques to magnetic resonance images stored as a matrix or array of pixel values. (Chen, col. 1, ll. 5-10, col. 1 ll. 64-66 and col. 3, ll. 20-21). These pixel values represent a grayscale intensity (i.e. luminance) of a human-readable image. (Chen, Abstract, lines 3-6). The pixel values are digital values. (Chen, col. 5, ll. 14-17). The pixel values, therefore, are values within a range of possible values bounded by definite limits; i.e., the dynamic range afforded by the number of bits used to represent the pixel values. Each pixel is processed sequentially. (Chen, col. 8, ll. 6-15). Therefore, Chen teaches successive transformation of luminance values that, together, define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

216. Narendra describes a system for implementation of an adaptive contrast enhancement scheme for image data using local area statistics (Narendra, p. 655, Abstract; p. 656, third paragraph). The image is represented by pixel values in an array. (Narendra, p. 657, col. 2, last paragraph). The pixel values represent intensity information (i.e. luminance) from a scene detected by imaging sensors. (Narendra, p. 655, Abstract, lines 3-6; p. 655, col. 2, Introduction, first paragraph, lines 1-2 and second paragraph, lines 2-3; p, 656, col. 1, fourth paragraph, lines 4-6). The luminance at each point is transformed based on local area statistics. (Narendra, p. 656, col. 2, Eq. 1). The luminance values are digital values and, therefore, are values within a range of possible values having defined limits. Therefore, Narendra teaches successive transformation of luminance values that collectively define an original image, each luminance value lying within a range of possible values that is bounded by definite limits.

217. The first means-plus-function element of claim 1 – the means for averaging – reads as follows:

> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;

218. It has been explained to me that, in order to properly interpret a means-plus-function claim element, one must first identify the function that the means is to perform and then one must review the specification to identify a structure, material or act corresponding to the identified function.

219. I understand that Polaroid contends that the function performed by the "means for averaging" is averaging electronic information signals corresponding to selected pluralities of pixels and to provide an average electronic information signal for each of the averaged pluralities of pixels. *See* Joint Claim Construction Statement (Corrected).

220. As above, Polaroid has taken the position that "*averaging*" should be construed to mean "calculating an intermediate value" and that "*average electronic information signal*" should be construed to mean "the signal providing pixel information, such as a color, luminance, or chrominance value of the calculated intermediate value." *See* Joint Claim Construction Statement (Corrected).

221. Polaroid has identified a low-pass filter or a block averager as the structure described in the '381 patent corresponding to this function. *See* Joint Claim Construction Statement (Corrected). That is, I understand Polaroid's position with respect to this claim element to be that the "means for averaging" is a structure that performs a low-pass filtering or block averaging function on a plurality of pixels to produce an intermediate value corresponding to the values of those pixels, or its equivalent.

222. As stated by Polaroid in the '381 patent, "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25; see also col. 3, line 62). I agree with the above-statement. As further evidence of these low-pass filtering and block averaging techniques are well-known, such techniques are taught by each of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen, and Narendra.

223. Gonzalez teaches systems that use averages for image enhancement. (Gonzalez, p. 161). In Equation 4.3-1, a formula is provided to calculate the arithmetic mean (average) of a number of pixel values from a selected neighborhood around the pixel being processed, indicated by S. Gonzalez teaches that a 3×3 neighborhood including nine pixels could be used, but also that "we are not limited to square neighborhoods". The intermediate calculated value of an average taught by Gonzalez may be implemented in a computing device, such as a software program running on a computer.

224. Richard teaches using a block averaging apparatus consisting of filters that receive a plurality of pixel values and output an intermediate value for those pixels. (see Richard, col. 3, lines 16-56). The means for computing a local mean value is made up of a horizontal-filtering device connected in series to a vertical filtering device. (Richard, col. 3, lines 16-20). The local mean value is an intermediate calculated value. These filtering devices provide a value representing the arithmetic mean of a plurality of pixel values in a window (i.e., a block) centered on the pixel being processed. (Richard, col. 3, lines 19-25). This value represents a value that would be obtained by computing the arithmetic mean of pixel values centered around the pixel value being processed. (Richard, col. 4, lines 49-53). Richard,

therefore, teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

225. Lee teaches using a block averager means that receives as input a plurality of pixel values and outputs an intermediate value calculated value for those pixels. (Lee, p. 165, last paragraph to p. 166, first paragraph). Equation 1 on page 166 produces an intermediate calculated value representing the average of these pixels. Lee further teaches that these algorithms are performed on digital computers. (Lee, P. 165, Introduction, line 1-2). As Lee further teaches making his algorithms more computationally efficient, it is evident that the block averager of equation 1 may easily be implemented on a computer. (Lee, P. 165, Introduction, 1st paragraph, last sentence; second paragraph). Therefore, Lee teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

226. Sabri teaches using a block averaging means for receiving as input a plurality of pixel values and outputs an average value (i.e., an intermediate calculated value) for those pixels. (see Sabri, col. 3, lines 35-68). In Sabri, an apparatus has a summing means (Fig. 1 and Fig. 2, element 14) which computes and outputs an average value from received input pixel values. (Sabri, col. 3, lines 38-45). The summing means of Figure 1 serves to compute for a group of pixels a weighted average value according to the identified formula. (Sabri, col. 3, 38-47). This formula computes the sum of each luminance value for a series of successive luminance values in a region defined by column *n* and row *m*. (Id.) Each luminance value in the defined region is multiplied by a fractional weighting coefficient and summed to provide a weighted average value. This weighted average is an intermediate calculated value that is provided for the group of luminance values. Sabri, therefore, teaches a block averager as well as a low-pass filter that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

227. Rangayyan describes using a block averager that receives as input a plurality of pixel values and outputs an intermediate calculated value representing an average for those pixels. (see Rangayyan, p. 561, col. 2, Section C, first paragraph). The average *a* is computed using a plurality of pixel values received as input. These plurality of pixels are the neighboring pixels forming a block (i.e., a matrix) centered around the pixel being processed. (Rangayyan, p. 561, col. 1, Section B, first paragraph). Therefore, Rangayyan teaches a block averager that receives as input a plurality of pixels and outputs an intermediate value for those pixels.

228. Chen teaches using a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels. (see Chen, col. 5, lines 25-50). The image filtering and enhancing circuit of Chen includes a pixel value averaging means. (Chen, col. 5., lines 25-26; Fig. 1, element 40). This averaging means computes and outputs an intermediate calculated value representing an average for a block of pixel values neighboring the pixel being processed. (Chen, col. 5, lines 35-42). Chen, therefore, teaches a block averager that receives as input a plurality of pixel values and outputs an intermediate value for those pixels.

229. Narendra teaches using a low-pass filter that receives as input a plurality of pixels and outputs an intermediate value for those pixels. (see Narendra, p.657, col. 2, first full paragraph). Narendra teaches implementing the local average function identified in Figure 2 as a low-pass filter ("LPF") as identified in Figure 4. The local average function is computed on a local area surrounding the pixel. (Narendra, p.656, col. 2, first full paragraph). Thus, Narendra, teaches a low-pass filter that receives as input a plurality of pixel values and outputs an intermediate value for those pixel values.

230. The Gonzalez algorithm operates on the input pixel itself, without taking an average. However, as I observe directly above, using a block average or low-pass filter in the

context of a contrast enhancement was well-known, as taught by any one of Gonzalez, Richard, Lee, Sabri, Rangayyan, Chen or Narendra. It would have been obvious to include the averages taught by those references in the Gonzalez algorithm to provide for local, rather than global, contrast. (Gonzalez, p. 160).

<u>…means for selecting and transforming….</u>

231. The second means-plus-function element of claim 1 – the means for selecting and transforming – reads as follows:

> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

232. Polaroid takes the position that the function performed by this means is that of selecting one of a plurality of different transfer functions for each of the succeeding pixels whereby each transfer function is selected as a function of (1) the electronic signal information for one pixel and (2) the average electronic information for the select plurality of pixels containing the pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic

information signals such that the ratio increases in correspondence with the increase in the value of the calculated intermediate value. *See* Joint Claim Construction Statement (Corrected).

233. I understand from the Joint Claim Construction Statement that Polaroid has identified the following formula, and equivalents of the formula, as the structure recited by the '381 patent for performing this function:

$$Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}, \text{ where } \gamma = (1+C)^{(Av/M-1)}$$

where Y_{OUT} is the transformed signal providing pixel information, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, C is a chosen number, Av is a calculated intermediate value, and M is any value within the dynamic range.

234. Therefore, I understand Polaroid's contention to be that the "means for selecting and transforming" is any algorithm that modifies a transformation function, such as $(Y_{MAX}(Y_{IN}/Y_{MAX}))$ using a power, γ, that includes the result of a ratio of a calculated intermediate value (Av) divided by any value within the dynamic range (M).

235. The Gonzalez algorithm teaches transforming an input signal where the transfer function is further selected as a ratio of the calculated intermediate values over a value in the range of values. The Gonzalez algorithm transforms an input pixel, *I*, into an output pixel value *FLEV* as follows:

$$FLEV = FH * \mathrm{EXP}(SS*(GN-I)) + 0.5$$

(Gonzalez, p. 454, see computation of variable SS). In the above computer instructions, the transfer function is selected as a ratio of the calculation intermediate value, ALOG (*FH/T*) over a value in the range of values because the function SS is computed as follows:

$$SS = (-1/GN) * \mathrm{ALOG}\,(FH/T)$$

(Gonzalez, p. 454, see computation of variable SS). *GN* represents the maximum value of the intended output device. *GN* therefore, is a value in a range bounded by definite limits (in this case 0 to 31). Therefore, Gonzalez teaches transforming an input signal, *I*, where the transfer function is further selected as a ratio of the calculated intermediate value, ALOG (*FH/T*) over a value in the range of values (in this case, *GN*).

236. Because Gonzalez algorithm suggests each and every element of claim 1, as it is proposed to be construed by Polaroid, I am of the opinion that claim 1 is invalid, as that concept has been explained to me.

237. Furthermore, as I have described above, each of Richard, Lee, Sabri, Rangayyan, Chen, and Narendra describe image processing systems that use transform functions to transform an input pixel value and that use block averagers (the “means for averaging”).

238. It is my opinion that combining the “means for selecting and transforming” of the Gonzalez algorithm with the image processing systems and methods described by Gonzalez is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Gonzalez reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, over Gonzalez in combination with the Gonzalez algorithm.

239. It is my opinion that combining the “means for selecting and transforming” of the Gonzalez algorithm with the image processing systems and methods described by Richard is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Richard reference and the Gonzalez algorithm.

Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Richard in combination with the Gonzalez algorithm.

240. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Lee is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Lee reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Lee in combination with the Gonzalez algorithm.

241. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Sabri is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Sabri reference and the Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Sabri in combination with the Gonzalez algorithm.

242. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Chen is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Chen reference and Gonzalez algorithm. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of the Chen reference in combination with the Gonzalez algorithm.

243. It is my opinion that combining the "means for selecting and transforming" of the Gonzalez algorithm with the image processing systems and methods described by Narendra is no more than arranging elements already well-known in the image processing field. Furthermore, the elements would continue to serve the same purpose and perform the same function in the proposed combination as they did in the Narendra and the Gonzalez algorithm references. Therefore, I am of the opinion that claim 1 is obvious, as that term has been explained to me, in view of Narendra in combination with the Gonzalez algorithm.

244. Claim 2 reads:

> The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

245. Claim 2, therefore, recites a method having all the elements of claim 1 and including the element that the transfer function is selected to provide higher contrast to pixels when a calculated intermediate value indicates a low light or high light condition. Such functions are suggested the combination of the Gonzalez algorithm with any one of Gonzalez, Richard, Rangayyan, Lee, or Narendra.

246. Gonzalez teaches selecting a transfer function to provide higher contrast between a pixel and its neighbors pixels when a calculated intermediate value represents a very dark or very light condition (Gonzalez, p, 141). Gonzalez teaches multiplying the difference between the value of an input pixel and the mean value of the neighboring pixels by a gain factor, *A(x,y).*

(Gonzalez, Eq. 4.2-14). The gain factor is calculated by multiplying a constant, *K,* by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. (Gonzalez, Eq. 4.2-15). This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because k is a constant and the global mean, m, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor to adapt to relative light levels in the image. By replacing the constant, *K,* with the mean value of the neighboring pixels so that the gain would increase in areas of low light or high light. Therefore, I believe that claim 8 is obvious in view of Gonzalez.

247. Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average |*p*-*a*|. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C*, will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

248. Rangayyan teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing that mean by the dynamic range of the electronic information signals. (Rangayyan, p. 561, Section C. Contrast Enhancement). Rangayyan teaches that the first step in transforming an input pixel value is to calculate a contrast measure, *C*. The value of *C* is arrived at by dividing the absolute value of the difference between the input pixel value, *p,* and the average value, *a,* of pixels surrounding the input pixel, $|p - a|$, by $(p+ a)$. (Rangayyan, p.561, col. 1, Equation for $C = |p - a|/(p+ a)$. The square root of the contrast factor, *C,* is calculated, C', and then used in a selected transfer function $p' = a(1+C')/(1-C')$, when $p>=a$ or $p' = a(1-C')/(1+C')$, when $p<a$. A new pixel value is then computed from p' using one of the following equations:

$$p''=255(p'-min)/(max-min); \text{ or}$$

$$p''=255(max-p')/(max-min).$$

The value of *max* represents the maximum pixel value and the value of *min* represents the minimum pixel value; *(max-min)* represents, therefore, the maximum dynamic range of the image. Rangayyan, therefore, teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing the mean by the dynamic range of the electronic information signals.

249. Lee teaches selecting a transfer function to provide higher contrast between the value of a pixel and its neighbors when a calculated intermediate value represents a very dark condition or a very light condition. Lee teaches a function $g(x)=ax+b$, where a=0.9 and b=13 "to allow contrast enhancement at both ends of gray scale." (Lee, p. 166, col. 1, last paragraph).

"The linear function … yields an effective constant stretch in both the highlights and the dark areas of the image." (Id.) I believe it would have been obvious to try replacing the linear function taught by Lee to a function that increased the "stretch" in areas of very low light or very high light, because that would allow Lee to further increase contrast at both ends of the gray scale. Therefore, I believe claim 8 is an obvious extension of Lee.

250. Narendra teaches that the local area mean is subtracted from the value of a pixel being processed and a gain is applied to the difference. (Narendra, p. 656, col. 2, second paragraph). The gain taught by Narendra is calculated by multiplying a constant, α., by the global mean of pixel values for the image and dividing that result by the standard deviation of neighborhood pixel values from the mean value for the neighborhood of pixels. This results in a gain that varies based on the standard deviation of the neighborhood pixel values, because α is a constant and the global mean, m, is a constant value for an image. I believe that it would have been obvious to try modifying the gain factor to adapt to relative light levels in the image. By replacing the constant, α, with the mean value of the neighboring pixels so that gain would increase in areas of low light or high light. Therefore, I believe claim 8 is obvious in view of Narendra.

251. Because each and every element of claim 2, as it is proposed to be construed by Polaroid, is suggested by the combination of the Gonzalez algorithm with any one of Gonzalez, Richard, Rangayyan, Lee, or Narendra, I am of the opinion that claim 2 is obvious in view of any combination of those references, as that concept has been explained to me.

252. Claim 3 reads:

> The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of

contrast provided in those areas of higher contrast provided by said select transfer function.

253. Claim 3, therefore, recites a method having all the elements of claim 2 and claim 1, and including the element that the transfer function is selected as a function of a determined constant, the value of which corresponds to the amount of contrast provided in areas of higher contrast. Such functions are suggested by the Gonzalez algorithm in combination with Gonzalez, Richard, Lee, or Narendra.

254. Gonzalez teaches that the transfer function is computed with a constant *k*, which is a value in the range between 0 and 1. (Gonzalez, p. 160, Equation (4.2-15)). In Equation (4.2-14), the transformation function g(x,y) applies a local gain factor A(x,y) to the difference between the pixel value being processed f(x,y) and the local mean m(x,y) of the neighborhood centered around f(x,y). (Gonzalez, p. 160, Equation (4.2-14). This gain factor A(x,y) amplifies local variations by multiplying the constant value *k* to the ratio of the global mean over the standard deviation of pixel values of the neighborhood. (Gonzalez, p.160, second paragraph). Since *A(x,y)* is inversely proportional to the standard deviation of pixel values, the areas with lower contrast receive larger gains. (Id.). An increase in the constant K will result in larger gains to these contrast areas. Gonzalez, therefore, teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. I believe, therefore that claim 9 is obvious in view of Gonzalez.

255. Richard teaches a system in which a constant value, *K*, can be adjusted by an operator to control the contrast. (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value Y_{ij} multiplied by (M_v/M_g), and further multiplied by this constant *K*. (Richard, Fig. 1) An increase in *K* will increase the contrast between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the

lightest areas of an image and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

256. Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$, added to the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a gain factor, *k*. (Lee, p.166, col. 1, Eq. 4). A higher value of *k* results in a higher output pixel value than a lower values of *k* will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Therefore, Lee teaches a system where increasing a constant increases the amount of contrast enhancement that is performed in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Lee.

257. Narendra teaches a transfer function using a locally adaptive gain factor based on a constant. (Narendra, p. 656, col. 2., Equation (1)). The gain factor G_{ij} is calculated by mulitplying a constant value, referred to as α, by the global mean (*M*) of the image brightness divided by the standard deviation (σ) from the mean of the brightness of pixels near the pixel being processed. (Id.). This constant of α may be any value between 0 and 1. As this constant increases, so will the gain factor. A higher gain factor results in a higher output pixel value than a lower gain factor will produce. A higher output pixel value will differ from its neighboring pixels more than a lower output pixel value will. Narendra, therefore, teaches a system where increasing a constant increases the amount of contrast enhancement that is performed. This will occur in areas of the image having higher contrast. I believe, therefore that claim 9 is obvious in view of Narendra.

258. Because each and every element of claim 3, as it is proposed to be construed by Polaroid, is suggested the combination of the Gonzalez algorithm and anyone of Gonzalez, Richard, Lee, Narendra, or Wang. I am of the opinion that claim 3 is obvious in view of any combination of those references.

V. ASSESSMENT OF NOVELTY AND OBVIOUSNESS OF THE CLAIMED INVENTION USING CLAIM CONSTRUCTION PROPOSED BY HP

259. I have also been asked to assess the novelty and obviousness of claims 1-3 and 7-9 assuming that the Court adopts HP's proposed claim constructions. I believe that claims 7-9 of the '381 patent are an obvious extension of Richard[11] and that claim 7 is an obvious extension of Sabri.[12] With respect to claims 1-3, I believe they are an obvious extension of Rangayyan[13] and that claim 1 is an obvious extension of Sabri. Again, I first assess claim 7, which is a method claim with a preamble and three separate steps: (1) an averaging step, (2) a selecting step and (3) a transforming step. I will assess the preamble and each of these steps in turn.

A method for continuously enhancing….

260. The preamble of claim 7 reads: "A method for continuously enhancing electronic image data received in a continuous stream of electronic information signals each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image."

261. I understand HP's position to be that "*continuously enhancing*" should be construed to mean "successively transforming" and that *"electronic information signals"* should

[11] A chart identifying how Richard suggests each and every element of claims 7-9 of the '381 patent, as those claims are proposed to be understood by HP, is attached as Appendix K.
[12] A chart identifying how Sabri suggests each and every element of claims 1 and 7 of the '381 patent, as those claims are proposed to be understood by HP, is attached as Appendix L.
[13] A chart identifying how Rangayyan suggests each and every element of claims 1-3 of the '381 patent, as those claims are proposed to be understood by HP, is attached as Appendix M.

be construed to mean “signals providing luminance pixel information.” See Joint Claim Construction Statement (Corrected).

262. HP also states that the phrase *“electronic image data received in a continuous stream of electronic information signals”* that appears in the preamble should be construed as “an uninterrupted stream of received luminance image data defining an original image to be recorded” and that the phrase “*each signal having a value within a determinate dynamic range of values”* should be construed as “each signal ha[ving] an associated luminance value that lies within a predetermined group of luminance values.” (Id.)

263. As construed by HP, the elements of the preamble are taught or suggested by Richard and Sabri.

264. Richard teaches methods for receiving and continuously enhancing a sequence of numerical values representing the luminance of pixels that make up a video image. (Richard, col. 1, ll. 58-61; col. 2, ll. 26-29). Richard teaches that a sequence of numerical pixel values representing luminance are received. (Richard, col. 2, ll. 26-29). Because each luminance value in Richard is a number expressed as a certain number of bits, every luminance value will lie within a predetermined group of luminance values. Richard further teaches that the system has an output terminal for delivering a sequence of numerical pixel values of luminance having enhanced contrast. (Richard, col. 2, ll. 24-25). The output values produced by Richard could be sent to a computing device for storage on, for example, a disk drive. Therefore, Richard teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that may be recorded, each luminance signal having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express the luminance value.

265. Sabri teaches systems and methods for continuously enhancing the quality of video image data originating as broadcast video signals. (Sabri, col. 1, ll. 9-14; col. 3, ll. 18-25). Sabri teaches that the broadcast signal is received as a stream signals from a source via an intervening analog-to-digital converter. (Sabri, col. 2, ll. 22-25). Each video image is defined as a series of signals (pel or picture element values), which include a luminance component. (Sabri, col. 2, ll. 4-32; col. 3, ll. 45-49; col. 4, ll. 44-49). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, ll. 18-21). For an 8-bit digital signal, the maximum range of values is 256. (Sabri, col. 2, ll. 44-46). The signals of Sabri will, therefore, lie within a predetermined group of luminance values. Therefore, Sabri teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each signal (picture element) having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.

<u>…averaging the electronic information signals…</u>

266. Following the preamble, claim 7 continues: "*averaging* the electronic information signals corresponding to selected pluralities of pixels and providing an *average electronic information signal* for each said plurality of pixels."

267. I understand that HP contends that "*averaging*" should be construed as "an arithmetic mean" and that "*average electronic information signal*", to the extent it needs to be construed, to mean "the average of the electronic information signals." *See* Joint Claim Construction Statement (Corrected).

268. As construed by HP, this step reads as calculating the arithmetic mean for a selected group of pixels. In connection with my analysis above of claim 7 using Polaroid's

construction, I observed that averaging electronic information signals, for example, by using low-pass filtering and block averaging techniques, was well-known and disclosed by at least each of Richard and Sabri. Even Polaroid, in the '381 patent, admits that "[l]ow-pass filtering and block averaging are both well-known techniques in the electronic arts and therefore need not be described in further detail herein." ('381 patent, col. 4, lines 23-25). I agree with this statement.

…selecting one of a plurality of different transfer functions…..

269. The next step of claim 7 reads: "selecting one of a plurality of different transfer functions for the electronic information signal for each of the plurality of succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel."

270. I understand that HP construes this step to mean that "each input pixel has an associated transfer function out of different transfer functions and the transfer function is selected based on the input pixel value, and the average that was formed using the input pixel value, where each input pixel is part of only one average". *See* Joint Claim Construction Statement (Corrected). Selecting a transfer function using an average is taught by Richard and Sabri but those references teach that a pixel can be part of multiple averages (that is, they teach use of a "moving block averager"). However, block averagers that calculate a single average for a group of pixels (known as "non-overlapping, block-by-block averagers") are a type of block averagers that is well-known. See, e.g, "Progressive Refinement of Raster Images," by Kenneth R. Sloan, Jr. and Steven L. Tanimoto, (IEEE Transactions on Computers, Vol. C-28, No. 11, November 1979) ("Sloan"). Therefore, I believe replacing a moving block averager with a non-

overlapping, block-by-block averager would be an obvious extension of the Richard and Sabri references.

271. Richard teaches that each input pixel has a transfer function selected based on its pixel value and the average of local mean, M_v, which includes the input pixel value. Richard teaches "means for multiplying the value of luminance of the point being processed by a variable coefficient which is proportional to the *ratio* M_v/M_g" (Richard, col. 1, lines 66-68). M_v is an average of luminance values of points which are adjacent to, and include, the pixel being processed for contrast enhancement. (Richard, col. 2, lines 19-22). Richard teaches that an input pixel value is transformed according to the following function: $Y_{ij}(M_v/M_g)*K$ The transfer function in Richard is, therefore, dependent on the input pixel value, Y_{ij}, and the average value of neighboring pixels (including the input pixel value), M_v. Although Richard does not explicitly teach a non-overlapping, block-by-block averager, I believe it would have been obvious to try to use such an averager to calculate the local mean value, M_v, in the Richard system because it would provide a local mean value and, among other reasons, would result in lower computational load on a system because only a single average value is calculated for each group of pixels.

272. Sabri teaches selecting a transform function based on the input pixel value and an average value of a group of pixels that includes the input pixel. (Sabri, col. 2, lines 4-14). A contrast enhancement factor γ_{ij} is derived from the pixel value itself, C_{ij}. (Sabri, col. 2, lines 29-39). The contrast enhancement factor is then added to a calculation that includes the average, φ, of the values of the pixel and the pixels preceding the pixel being processed. (Sabri, col. 2, lines 40-46). Sabri, therefore, teaches selecting a transform function based on the input pixel value and an average value of a group of pixels that includes the input pixel. Although Sabri does not explicitly teach a non-overlapping, block-by-block averager, I believe it would have been

obvious to try to use such an averager to calculate the local mean value, M_v, in the Sabri system because it would provide a local mean value and, among other reasons, would result in lower computational load on a system because only a single average value is calculated for each group of pixels.

<u>….transforming the electronic information signal….</u>

273. The last step of the method of claim 7 recites:

> transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said transfer function is selected further as a function of the ratio of the value of the average electronic information signal to a select proportionate value of the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

274. HP provides the following definition for the transformation step:

> each input pixel that has been part of the averaging step is altered based on the corresponding average electronic information signal to which it is associated and based on the result of dividing a first existing data value representing the average electronic information signal by a second existing data value representing a select proportionate value of the dynamic range of the average electronic information signals. *See* Joint Claim Construction Statement (Corrected).

275. As construed by HP, such functions are taught by each of Richard and Sabri.

276. Richard teaches altering an input signal using the pixel value itself, an arithmetic mean of the value of a group of pixels associated with the pixel and is further based on the result of dividing the arithmetic mean associated with the pixel group by an integer value within a range of values that represent the dynamic range. The transformation function depicted as element 5 in Figure 1 of Richard alters an input signal by multiplying the value of the pixel, Y_{ij}, by the ratio of the local mean value of nearby pixels, M_v, to the global mean value of the image, M_g, and further multiplies that by a constant K. (Richard, Figure 1, elements 10-14). As taught by Richard, therefore, a pixel's value is altered based on the starting value of the pixel, Y_{ij}, and based on the result of dividing the local average, M_v, by a select proportionate value of the

dynamic range, $M_{g.}$ The global mean of pixel values of an image, by definition, will always have a value that lies within the dynamic range of the image. Further, because $1/M_g$ is the output of a ROM memory element, M_g may only take on a finite number of digital values. Richards teaches a represented by a finite number of bits. (*See,* e.g., FIG. 1 of Richard in which M_g is the output of a ROM memory element). Richard, therefore, teaches altering an input signal using the pixel value itself, an arithmetic mean of a group of values of pixels associated with the pixel and is further based on the result of dividing the arithmetic mean of a group of values of pixels associated with the pixel by a value within a range of values that represent the dynamic range.

277. Sabri teaches altering an input signal using the pixel value, the calculated arithmetic mean for the group of pixels neighboring including the subject pixel (?) and is based on the result of dividing the calculated arithmetic mean by an integer value within a range of values that represent the dynamic range. (Sabri, Fig. 1). The value of the transformation function B_{ij} is computed from an average referred to as ϕ and a contrast enhancement factor referred to as γ_{ij}. (Sabri, col. 2, lines 40-46). The contrast enhancement signal is derived from the input video signal, C_{ij}. (Sabri, col. 2, lines 29-39). Thus, the transformation function uses the pixel value of the input pixel. The average, φ, represents the average pixel values for a group of pixels in the neighborhood of the pixel being processed, including the input pixel. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). The average, ϕ, is divided by the maximum range, *R*, of the signal (for example, 256 in an 8-bit system). (Sabri, col. 2, lines 40-46). Therefore, Sabri also teaches altering an input signal using the pixel value itself, the calculated arithmetic mean for the associated group of pixels and is based on the result of dividing that calculated arithmetic mean by an integer value within a range of values that represent the dynamic range.

278. Because each and every element of claim 7, except for use of a non-overlapping, block-by-block averager, is found in each of Richard and Sabri, and because I believe that use of a non-overlapping, block-by-block averager is an obvious extension to the subject matter of claim 7, I am of the opinion that claim 7, as proposed to be construed by HP, is obvious, as that concept has been explained to me, when compared to either reference. For the same reason, claim 7 would be anticipated by each of Richard and Sabri if a non-overlapping block by block although were not a claim requirement.

Claim 8

279. Claim 8 reads:

> The method of claim 7 wherein the transfer function is selected in response to an average electronic information signal indicative of low scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and in response to an average electronic information signal indicative of high scene light intensity levels to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

280. Claim 8, therefore, requires a method having all the elements of claim 7 and the additional element that the transfer function is selected to provide higher contrast to pixels when the calculated arithmetic mean indicates a low light or high light condition. Such functions are taught by Richard.

281. Richard teaches selecting a transfer function to provide higher contrast for a pixel when the calculated arithmetic mean represents a very dark or very light condition. The contrast amplifier of Richard decreases the luminance value or increases the luminance value of a pixel being processed responsive to the ratio M_v/M_g. (Richard, col. 5, line 62 to col. 6, line 3). The contrast amplifier reduces the luminance value of the pixel being processed closer to black when the local mean value associated with the pixel is less than the global mean value for the image as

a whole and increases the luminance value of the pixel being processed closer to white when the local mean value associated with the pixel is greater than the global mean value for the image as a whole. (Id.) "In the case of areas which are darker than the general mean value, these areas have an even darker appearance after processing." (Richard, col. 6, lines 10-14). Richard provides higher contrast for very dark and very light pixels because the ratio of Mv/Mg will be very close to 0 (for very dark pixels) and will be greater than one for very light pixels. This means that the value of a very dark pixel will be multiplied by a fraction, resulting in a darker appearance for the darkest pixels as compared to less dark pixels and a very light pixel will be multiplied by a number greater than 1, which will result in a lighter appearance for the lighter pixels as compared to less light pixels. Richard, therefore, teaches selecting the transfer function to provide higher contrast within the dark and light regions of an image.

282. I, therefore, believe that claim 8, as proposed to be construed by HP, is an obvious extension of Richard.

283. Claim 9 reads:

> The method of claim 8 wherein said transfer function is selected further as a function of a determined constant wherein increasing the value of said constant operates to increase the contrast in those areas of higher contrast provided by said select transfer function.

284. Claim 9, therefore, recites a method having all the elements of claim 8 and claim 7, and the additional element that the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

285. Richard teaches a system in which a constant value, *K*, can be determined by an operator to increase the contrast in areas of higher contrast. (Richard, col. 5, lines 55-58). The new pixel value is the input pixel value Y_{ij} multiplied by (M_v/M_g), and further multiplied by this

constant *K*. (Richard, Fig. 1) An increase in *K* will increase the contrast between the darkest areas of an image and neighboring dark parts of the image, and, similarly, will increase the contrast between the lightest areas of an image and neighboring less light areas of that image. Therefore, Richard teaches the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed.

286. Therefore, I am of the opinion that claim 9, as it is proposed to be construed by HP, is an obvious extension of Richard.

<u>Claim 1</u>

287. Independent claim 1 consists of a preamble and two Gonzalez claim elements : a means for averaging; and a means for selecting and transforming.

288. The preamble of claim 1 reads as follows:

> A system for continuously enhancing electronic image data received in a continuous stream of electronic information signals, each signal having a value within a determinate dynamic range of values and corresponding to one of a plurality of succeeding pixels which collectively define an image

289. I understand HP's position to be that "*continuously enhancing*" should be construed to mean "successively transforming" and that *"electronic information signals*" should be construed to mean "signals providing luminance pixel information." See Joint Claim Construction Statement (Corrected).

290. HP also states that the term *"electronic image data received in a continuous stream of electronic information signals"* that appears in the preamble should be construed as "an uninterrupted stream of received luminance image data defining an original image to be recorded" and that the term "*each signal having a value within a determinate dynamic range of*

values" should be construed as "each signal has an associated luminance value that lies within a predetermined group of luminance values." (Id.)

291. As construed by HP, each of the elements of the preamble are taught by each of Sabri and Rangayyan.

292. Sabri teaches systems and methods for enhancing the quality of video images, which are electronic image data, originating as broadcast video signals. (Sabri, col. 1, ll. 9-14; col. 3, ll. 18-25). Sabri teaches that the broadcast signal is received as a stream signals from a source via an intervening analog-to-digital converter. (Sabri, col. 2, ll. 22-25). Each video image is defined as a series of signals (pel or picture element values), which include a luminance component. (Sabri, col. 2, ll. 4-32; col. 3, ll. 45-49; col. 4, ll. 44-49). The video signals of Sabri can be in digital form, for example 8 bits. (Sabri, col. 3, ll. 18-21). For an 8-bit digital signal, the maximum range of values is 256. (Sabri, col. 2, ll. 44-46). The signals of Sabri will, therefore, lie within a predetermined group of luminance values. Therefore, Sabri teaches successive transformation of an uninterrupted stream of received luminance image data defining an original image that could be recorded, each signal (picture element) having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.

293. Rangayyan teaches methods for performing adaptive local contrast enhancement on a series of pixels received via acquisition devices, the pixels collectively defining an image. (Rangayyan, Section A). The pixel values provide pixel information, such as luminance. (Rangayyan, Section A, ll. 24-30). Since each pixel value in Rangayyan is a number expressed as six bits, every pixel value will lie within a predetermined group of luminance values. Therefore, Rangayyan teaches successive transformation of an uninterrupted stream of received

luminance image data defining an original image that could be recorded, each luminance signal having an associated luminance value that lies within a predetermined group of luminance values defined by the number bits available to express luminance values.

…means for averaging…

294. The first means-plus-function element of claim 1 – the means for averaging – reads as follows:

> means for averaging electronic information signals corresponding to selected pluralities of pixels and providing an average electronic information signal for each said plurality of pixels so averaged;

295. It has been explained to me that, in order to properly interpret a "means-plus-function" claim element, one must first identify the function that the means is to perform and then one must review the specification to identify a structure, material or act corresponding to that function.

296. I understand that HP states that the function performed by the "means for averaging" is providing an average for selected pixel values around one pixel, where the average is correlated to each pixel making up the average. *See* Joint Claim Construction Statement (Corrected). HP has identified a block averager with a buffer memory that takes luminance values as an input and outputs an average luminance value that is correlated to each pixel in the block, and equivalents of that structure. *See* Joint Claim Construction Statement (Corrected).

297. In connection with my analysis above of claim 7 using Polaroid's construction, I discussed that averaging electronic information signals, for example, by using low-pass filtering and block averaging techniques are well-known and are taught by at least, Sabri or Rangayyan.

298. Further to the Sabri and Rangayyan references, it would be natural to use one or more buffer memories as in HP's construction. For example, many of these references execute

an averager or low-pass filter on a computing device. The computing device would use one or buffers in memory for storing any input value, intermediate calculated values or output values in performing the averaging.

…means for selecting and transforming…

299. The second means-plus-function element of claim 1 – the means for selecting and transforming – reads as follows:

> means for selecting one of a plurality of different transfer functions for the electronic information signal for each of the succeeding pixels in a manner whereby each transfer function is selected as a function of the electronic information signal for one pixel and the average electronic information signal for the select plurality of pixels containing said one pixel and for subsequently transforming the electronic information signal corresponding to each pixel by the transfer function selected for that pixel wherein said selecting and transforming means further operates to select said transfer function as a function of the ratio of the value of the average electronic information signal to the dynamic range of the electronic information signals such that the ratio increases in correspondence with the increase in the value of the average electronic information signal.

300. HP states that function performed by this means is that of selecting a transfer function for each incoming pixel based on the pixel value and the average electronic information signal values of a group of pixels that includes the subject pixel, and based on the result of dividing a first existing data value representing the average electronic information signal of the group of pixels by a second existing data value representing the dynamic range of the average electronic information signals. *See* Joint Claim Construction Statement (Corrected).

301. I understand from the Joint Claim Construction Statement that HP has identified the circuitry in Fig. 4 of the '381 patent as the structure corresponding to this function which computes the following function:

$$Y_{OUT} = Y_{MAX}(Y_{IN}/Y_{MAX})^{\gamma}, \text{ where } \gamma = (1+C)^{(Av/M-1)}$$

where Y_{OUT} is the transformed signal providing pixel information, Y_{MAX} is the highest value of the dynamic range, Y_{IN} is the input signal providing pixel information, C is a chosen number, Av is the average electronic information signal of a corresponding group of pixels, and M is the dynamic range of the electronic information signals.

302. I have not found any references that explicitly disclose the circuit described in Fig. 4 of the '381 patent. However, I understand that Polaroid may take the position that any computer implementing the algorithm set forth in paragraph 319, above, is an infringing structure. If that is determined to be the case, then each of Sabri and Rangayyan teach the element of selecting and transforming the input.

303. Sabri teaches selecting a transfer function using the pixel value itself and the calculated arithmetic mean for the group of pixels that includes and neighbors the subject pixel and also based on the result of dividing the mean by a value equal to the dynamic range of the electronic information signals. (Sabri, Fig. 1). The value of the transformation function B_{ij} is computed from an average referred to as ϕ and a contrast enhancement factor referred to as γ_{ij}. (Sabri, col. 2, lines 40-46). The contrast enhancement factor is derived from the input video signal, C_{ij}. (Sabri, col. 2, lines 29-39). Thus, the transformation function uses the pixel value of the input pixel. The average, ϕ, represents the average pixel values for a group of pixels in the neighborhood of the pixel being processed, including the input pixel. (Sabri, col. 2, lines 18-27, col. 3, lines 35-50). The average, ϕ, is divided by the maximum range, R, of the signal (for example, 256 in an 8-bit system). (Sabri, col. 2, lines 40-46). Therefore, Sabri also teaches using a function that transforms an input signal using the pixel value itself, the calculated arithmetic mean for the associated group of pixels and is based on the result of dividing that mean by the dynamic range of a value equal to the electronic information signals.

304. Rangayyan teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing that mean by a value equal to the dynamic range of the electronic information signals. (Rangayyan, p. 561, Section C. Contrast Enhancement). Rangayyan teaches that the first step in transforming an input pixel value is to calculate a contrast measure, *C*. The value of *C* is arrived at by dividing the absolute value of the difference between the input pixel value, *p,* and the average value, *a,* of pixels surrounding the input pixel, $|p - a|$, by $(p+ a)$. (Rangayyan, p.561, col. 1, Equation for $C = |p - a|/(p+ a)$). The square root of the contrast factor, *C,* is calculated, C', and then used in a selected transfer function $p' = a(1+C')/(1-C')$, when $p >= a$ or $p' = a(1-C')/(1+C')$, when $p < a$. A new pixel value is then computed from *p'* using one of the following equations:

$$p'' = 255(p' - min)/(max - min); \text{ or}$$

$$p'' = 255(max - p')/(max - min).$$

The value of *max* represents the maximum pixel value and the value of *min* represents the minimum pixel value; *(max-min)* represents, therefore, the maximum dynamic range of the image. Rangayyan, therefore, teaches selecting a transfer function using the input pixel value, the calculated arithmetic mean for a group of pixels that surrounds and includes the input pixel and that is based on the result of dividing the mean by a value equal to the dynamic range of the electronic information signals.

305. Because each and every element of claim 1, as it is proposed to be construed by HP, is suggested by Sabri or Rangayyan, I am of the opinion that claim 1 is invalid, as that concept has been explained to me.

306. Claim 2 reads:

> The system of claim 1 wherein said selecting and transforming means is responsive to an average electronic information signal indicative of low scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the lowest scene light intensity levels and is further responsive to an average electronic information signal indicative of high scene light intensity levels for transforming the electronic information signals to provide a higher contrast to those electronic information signals corresponding to pixels having the highest scene light intensity levels.

307. Rangayyan teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition (Rangayyan, p. 561, Section B. Contrast Enhancement). The contrast measure *C* calculates the difference between the pixel value itself and the neighborhood average $|p\text{-}a|$. (Rangayyan, p. 561, see Equations for C and p'). In very light or very dark areas, the contrast measure, *C*, will be a small number, which will be made larger when the square root of it is taken. As result, the transformation function *p'* will increase the difference in value for pixels having small differences from their neighborhood average, as would typically be the case in a very dark or very light area. This is evident from the before and after results of contrast enhancement shown in Figures 2-10. (Rangayyan, pages 561 and 562, Figures 2-10). Rangayyan, therefore, teaches selecting a transfer function to provide higher contrast to a pixel when the arithmetic mean of pixel values surrounding the pixel being processed indicates a very dark or very light condition.

308. Claim 2, therefore, recites a method having all the elements of claim 1 and the additional element that the transfer function is selected to provide higher contrast to pixels when

an average value indicates a low light or high light condition. Such functions are taught by Rangayyan.

309. Because Rangayyan suggests each and every element of claim 2, I am of the opinion that claim 2, as it is proposed to be construed by HP, is an obvious extension of Rangayyan.

310. Claim 3 reads:

> The system of claim 2 wherein said selecting and transforming means further operates to select said transfer function as a function of a determined constant whose value corresponds to the amount of contrast provided in those areas of higher contrast provided by said select transfer function.

311. Claim 3, therefore, recites a method having all the elements of claim 2 and claim 1, and the additional element that the transfer function is selected as a function of a determined constant, where increasing the constant increases the amount of contrast enhancement that is performed. In effect, claim 3 is directed to a "gain factor" that can be used to increase contrast between pixels.

312. Gain factors are well-known in the art, see, e.g., Gonzalez, Richard, Lee, Sabri, Narendra and Wang. Gonzalez teaches that the transfer function is computed with a determined constant *k*, which is determined to be a value in the range between 0 and 1 and which controls the gain. (Gonzalez, p. 160, Equation (4.2-15)). Richard teaches a system in which a constant value, *K*, can be determined by an operator to control the contrast applied to an image. (Richard, col. 5, lines 55-58). Lee teaches an algorithm in which the new pixel value, $x'_{i,j}$, is equal to the local mean, $m_{i,j}$ plus the input pixel value minus the local mean, $x_{i,j}$-m_{ij}, multiplied by a determined gain factor, *k*. *k*, therefore, controls the gain. (Lee, p.166, col. 1, Eq. 4). Chen teaches using a constant *k* for adjusting the contrast calculated by the selected transfer function.

(Chen, col. 1, lines 22-49). Sabri teaches using determined constants to control contrast enhancement. (Sabri, col. 2, lines 29-39). Narendra teaches a transfer function using a locally adaptive gain factor based on a determined constant. The constant, threefore, controls the gain. (Narendra, p. 656, col. 2., Equation (1)). Wang teaches using the contrast gain factor of a determined constant *k*. (Wang, p. 376, Equation (6-4)). I believe that one of ordinary skill in the art would have found it obvious to modify the techniques of Rangayyan to try to use a gain factor, as described by any one of the references above, to increase contrast in a processed image.

VI. CONCLUSION

It is my opinion that the subject matter of claims 1-3 and 7-9 of the ‘381 patent lack novelty or are otherwise obvious in view of the disclosures of the above-identified prior art references.

Rangaraj Rangayyan, Ph.D.

EXHIBIT B

IN THE UNITED STATES DISTRICT COURT

FOR THE DISTRICT OF DELAWARE,

POLAROID CORPORATION,	)	
Plaintiff,	)	
vs.	)	No. 06-738 (SLR)
HEWLETT-PACKARD,	)	
Defendant.	)	

** CONFIDENTIAL **

The deposition of Dr. Rangaraj M. Rangayyan, called for examination, taken pursuant to the provisions of the Code of Civil Procedure and Rules of the Supreme Court of the State of Illinois pertaining to the taking of depositions for the purpose of discovery taken before LISA SCHWAM, CSR No. 84-004650, a Notary Public within and for the County of Cook, State of Illinois, and a Certified Shorthand Reporter of said state, at 54th Floor, 200 East Randolph Street, Chicago, Illinois, commencing, on the 9th day of May, A.D. 2008, at 8:07 a.m.

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A. Yes. In looking at item 241 in my report -- my initial expert report -- combining the means for selecting and transforming of the Gonzalez algorithm with the image processing systems and methods described by Sabri and so on, I have reached the conclusion at the end of item 241 that I am of the opinion that Claim 1 is obvious in view of Sabri in combination with the Gonzalez algorithm.

19:31:52

19:32:24

Q. And did you come to an opinion why one of skill in the art would attempt to combine the teachings of Sabri with those found in the Gonzalez algorithm?

A. I'm sorry. Was the question why one would do it?

19:32:59

Q. Did you provide an opinion or did you reach a conclusion as to why one of skill in the art would combine the teachings of Sabri with those found in the Gonzalez algorithm?

A. That could be left open. It depends upon the end goal of the person who would put multiple methods together. Depending upon the combination employed of the multiple methods, the end result could be different.

19:33:28

So I cannot say what the aim or purpose of that could possibly be. Different results could be achieved.